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COMMITTEE ON THE PEACEFUL USES OF
OUTER SPACE

IMPLEMENTATION OF THE RECOMMENDATIONS OF THE SECOND UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE:

ACTIONS BY INTERNATIONAL ORGANIZATIONS

Report of the Secretariat in response to the request of the Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space

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INTRODUCTION

1. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), in the report on the work of its fourth session, made a series of recommendations concerning the preparation of reports and studies by the Secretariat and the compilation of information from Member States (A/AC.105/456, annex II, paras. 4, 5 and 6).

2. In particular, in paragraph 6 (a) of its report, "in order to permit a better assessment of the implementation of the recommendations of UNISPACE 82, the Working Group recommended that, as a first step," the following report be prepared:

> "(a) A report dealing with the implementation of the recommendations of UNISPACE 82 addressed to specialized agencies and other international organizations, as listed in annexes I and II of A/AC.105/451, on the basis of information provided by those agencies and organizations".

3. The report of the Working Group was adopted by the Scientific and Technical Sub-Committee at its twenty-seventh session (A/AC.105/456, para. 21) and the recommendations were endorsed by the Committee on the Peaceful Uses of Outer Space at its thirty-third session 1/ and by the General Assembly in paragraph 10 of its resolution 45/72 of 11 December 1990.

4. In accordance with the recommendation of the Working Group in paragraph 6 (a) of its report, the Secretariat addressed a letter dated 8 August 1990 to specialized agencies and other international organizations concerned with outer space, and a letter dated 12 September 1990 to other offices of the Secretariat concerned with outer space, requesting them to provide information on any actions they had undertaken to implement the UNISPACE 82 recommendations.

5. The substantive responses received up to 15 January 1991 are reproduced below. Responses received subsequent to that date will appear in an addendum to the present document.

1/ Official Records of the General Assembly, Forty-fifth Session, Supplement No. 20 (A/45/20), para. 30.

I. UNITED NATIONS

DEPARTMENT OF TECHNICAL CO-OPERATION FOR DEVELOPMENT

[Original: English]

The Natural Resources and Energy Division of the Department of Technical Co-operation for Development provides technical assistance to developing countries in the planning, construction, maintenance and operation of a large variety of public works. Cartography, surveying and mapping and remote sensing are vital tools in the planning and operation of infrastructure activities, and they are therefore included in the functions of the Division.

As of 1990, about 35 countries had received technical assistance and advisory services in remote sensing which resulted in project designs for further implementation either on a multinational or bilateral assistance level. The range of technical assistance covered a wide range of activities, from the simple processing of remote sensing data to establishing the infrastructure of a fully developed remote sensing centre.

Technical co-operation activities in remote sensing include the preparation of projects for the establishment of remote sensing centres on national as well as regional levels. These projects focus on providing interpretation equipment, training and institutional support with the long-term objectives of enabling developing countries to use this technology autonomously in support of their development programmes.

Assistance in institution building or direct support for remote sensing applications is provided by means of technical co-operation projects to which both the United Nations and the requesting Government contribute. For its part, the Department of Technical Co-operation for Development makes available technical advisory services rendered by staff members and international experts, assists in the training of local personnel, both in-country and overseas, and provides various items of the equipment needed to meet the objectives of the projects. Normally, the Government contributes, inter alia, in-country facilities, support personnel, as well as provision, in some instances, of national professionals.

OFFICE OF THE UNITED NATIONS DISASTER RELIEF CO-ORDINATOR

[Original: English]

The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) has undertaken several steps in the use of space technology. UNDRO started to implement its programme on disaster satellite communications in March 1990 by organizing an international conference on disaster communications, attended by potential users of emergency communications and producers or owners of satellite communications technology. The Conference identified UNDRO's major needs and recommended that UNDRO be the focal point for promoting the use of communications and remote sensing technology in disaster relief, preparedness and prevention.

As a further step in UNDRO's disaster communications activity, the procurement of radio-satellite terminals is in process, to be followed by a training course organized for UNDRO staff. Implementation of further projects and activities in 1991-1992, as recommended by the above UNDRO Conference, is now under consideration.

II. SPECIALIZED AGENCIES

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

[Original: English]

Concerning assistance to Member States in the area of remote sensing (paragraph 173 of the UNISPACE 82 report (A/CONF.101/10))

As a follow-on to the recommendations of UNISPACE 82, the Food and Agriculture Organization (FAO) has strengthened and restructured its Remote Sensing Centre in order to focus its activities on priority areas identified by UNISPACE 82 (see figure I, containing an organizational diagram of the Centre).

Activities of the Technology Transfer Group are particularly relevant to the recommendations listed in paragraph 173. Their overall objective is the strengthening of indigenous capacities of developing countries in the operational applications of remote sensing in the agriculture, forestry and fisheries sectors.

In the framework of remote sensing technology transfer activities, FAO is organizing training courses and workshops, conducting pilot studies, providing information and advisory services and functioning as a clearing-house within the United Nations system for remote sensing information relevant to renewable natural resources.

FAO, often in co-operation with other United Nations bodies, Member States and international organizations, organizes up to 10 practically oriented remote sensing training courses annually. However, during the last year only seven courses could be organized because of lack of funds. The main support for the FAO remote sensing training courses has been provided by Italy. Australia, Canada, Germany, France, the Netherlands, Spain and Czechoslovakia have also co-operated with FAO in remote sensing training. Some of these courses are organized jointly with the United Nations Outer Space Affairs Division, the Regional Remote Sensing Project of the Economic and Social Commission for Asia and the Pacific (ESCAP), the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Office of the United Nations Disaster Relief Co-ordinator (UNDRO), the World Health Organization (WHO), the World Meteorological Organization (WMO), and with the European Space Agency (ESA). National courses are always organized at the request of and in co-operation with the host country. Due to budgetary constraints, the FAO remote sensing training activities will have to be further reduced if the required external funding does not materialize.

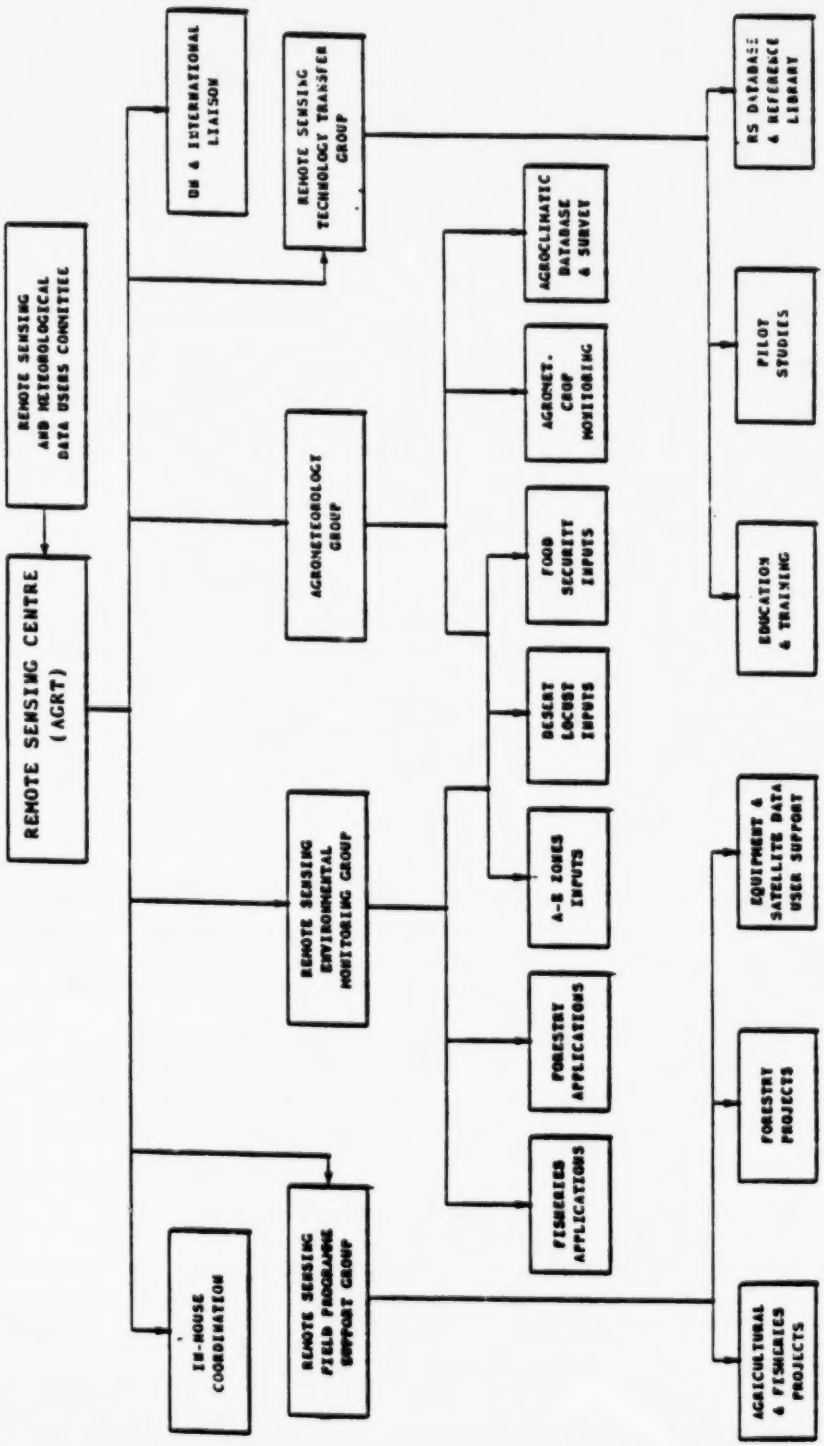

Figure 1. Organizational diagram of the Food and Agriculture Organization of the United Nations (FAO) Remote Sensing Centre. For 1990 to 1991.

FAO remote sensing pilot studies are used to test the suitability of satellite image data and interpretation techniques in specific applications required for implementation of FAO field projects. France funded nine FAO pilot studies on the application of satellite high-resolution image data in agricultural, forestry and fisheries projects, as follows:

- Soil mapping at 1:250,000 and 1:50,000 scale (Botswana);
- Soil erosion susceptibility assessment and assistance to land conservation planning (Brazil);
- Agriculture statistics (Ethiopia);
- Irrigation management and monitoring (Indonesia);
- Coastal studies (Philippines);
- Forestry mapping and monitoring (global services);
- Irrigation potential and land development (Chad);
- Tse tse habitat mapping (United Republic of Tanzania).

The European Space Agency funded a pilot study for developing an operational methodology for the application of satellite synthetic aperture radar (SAR) data in land use and vegetation cover mapping. The field tests were conducted in Tunisia.

Advisory services provided by the Centre include information on the availability and suitability of remote sensing data, equipment, techniques, education and training, assistance with the formulation of training activities, selection of experts and consulting companies, recommendations on institutional infrastructures and functional linkages between remote sensing units and users of their services.

An important role of the FAO Remote Sensing Centre is to function as a clearing-house for remote sensing information relevant to agriculture, food security, forestry and fisheries, with special emphasis on developing countries. This function is being implemented through the development of a remote sensing reference library focused on applications to renewable natural resources in developing countries.

Concerning the strengthening and expansion of data banks (paragraph 211 of the UNISPACE 82 report)

The FAO Remote Sensing Centre has undertaken the development of a remote sensing information database consisting of the World Index of Space Imagery (WISI) and the World Aerial Photographic Index (WAPI) in co-operation with member countries. At present, the remote sensing information database is geographically limited to developing countries. The priority in its development was given to

African countries where the lack of information on the existing air-photo, SAR/SLAR and other remote sensing coverage is one of the serious obstacles in preparing development projects.

The FAO remote sensing information database has the following objectives:

(a) To link the national and international remote sensing databases to obtain timely information on available remote sensing coverage relevant to thematic mapping and to inventory renewable resources in developing countries;

(b) To establish an operational indexing system for remote sensing data which will permit the integration of information on air-photo and satellite remote sensing coverage;

(c) To assist in upgrading the national remote sensing databases in developing countries.

At present, WISI consists of the following three components:

(a) Telecommunication links with participating remote sensing databases through the SILENT 700 terminal;

(b) A Landsat data bank containing a complete, single-date coverage of developing countries with 70 mm chips (four multispectral scanner (MSS) bands);

(c) A Landsat microfiche and microfilm library, containing listings of Landsat scenes recorded by United States receiving stations, and partial coverage of scenes recorded by non-United States Landsat receiving stations. Each record contains the satellite path and row number, date of coverage, image quality for each band, availability of digital imagery, cloud cover and other descriptive parameters. The microfilm, when available, is particularly suitable for assessment of cloud location.

FAO participates, through telecommunication links, in the remote sensing conference system of the United States National Oceanographic and Atmospheric Administration (NOAA). That system has been frequently used to obtain information on the availability and parameters of NOAA/AVHRR (Advanced Very High Resolution Radiometer) imagery. Direct links are also available with the Earth Observation Satellite Company (EOSAT) and the SPOT IMAGE company.

Landsat 70 mm MSS chips, most of which date from the early 1970s, are used as a reference database to which changes in land use, land degradation and vegetation cover are related.

Collection of input data for compilation of the FAO World Aerial Photographic Index (WAPI) involves two stages. In the first stage, data are extracted from returned questionnaires sent to all participating countries. However, often important information, such as date of aerial photography or availability of films, is missing. Furthermore, some countries do not return the questionnaires. In the second stage, a consultant visits the countries and fills in the missing information as far as possible.

The completed comprehensive air-photo indexes are sent to the respective countries, where they are continually updated. The FAO Remote Sensing Centre stores one copy in its WAPI database. At present, WAPI is being expanded to provide information on air-photo coverage in Latin America and the Caribbean.

The ARTEMIS (Africa Real-Time Environmental Monitoring using Imaging Satellites) database is a dedicated system for vegetation and precipitation monitoring in Africa based on environmental satellites. In August 1988 it was installed in the FAO Remote Sensing Centre, and since then it has been generating a wide range of satellite-based vegetation and precipitation assessments of Africa in 10-day and monthly intervals.

The ARTEMIS databases are as follows:

- Vegetation index for Africa based on NOAA-AVHRR-GAC (global area coverage) data (available since January 1982);

- Estimated rainfall based on Meteosat thermal infrared data (available since September 1988 for June-October and for the Sahelian area only);

- Number of rainfall days, based on Meteosat thermal infrared data (available since September 1988 for the whole of Africa);

- Cold cloud duration, based on Meteosat thermal infrared data (available since September 1988 for the whole of Africa).

The FAO remote sensing information databases, when completed, would enable more efficient utilization of the existing remote sensing coverage of Africa and would contribute to the establishment of an integrated, geographically-based indexing system for aerial and satellite remote sensing data for African member countries. Considering the high cost of new aerial photography and the non-availability of new satellite remote sensing coverage for most parts of Africa, the establishment of such an operational system has long been overdue. However, external funding will be necessary to develop the remote sensing information database of Africa to full operational status.

Regarding the recommendation that FAO and regional remote sensing centres should continue to assist Member States in the development of remote sensing of renewable resources, including the provision of training, the related FAO services are mostly provided as part of the implementation of field projects. These projects include assistance for development and strengthening of remote sensing institutions; mapping and assessment of renewable natural resources; monitoring of changes in land use, land degradation and vegetation cover; assessment of damage caused by natural disasters; improvement of crop area estimates, etc. Particular attention is paid to the development of remote sensing components for national and regional early warning systems on food security. National projects always include training of counterpart staff to ensure continuation of relevant activities after projects are terminated.

Examples of national remote sensing projects supported at present by the Centre include:

A. Africa

Benin: Land cover/ecological map at 1:200,000 scale;

Côte d'Ivoire: Strengthening of remote sensing activities for agricultural development;

Liberia: Land use and vegetation mapping at 1:250,000 scale;

Regional project under development: Preparatory assistance in developing remote sensing and geographic information system (GIS) capacity for small-scale mapping of land use and vegetation cover.

B. Middle East

Egypt: Assisting with the establishment of a remote sensing unit at the Agricultural Research Centre;

Lebanon: Remote sensing technical assistance in planning for rural development. Remote sensing component: 1:50,000 land use/cover map from Landsat, Spot and Soyuz imagery;

Libya: Assisting with the formulation of a project for a comprehensive agrarian reform programme.

C. Asia

Bangladesh: Ten pilot studies for application of remote sensing technology in agriculture, forestry and fisheries sectors;

Afghanistan: Pipeline project for development of a reliable geographic database for agricultural and other natural resources;

Philippines: Contribution to the formulation of a project for a comprehensive agrarian reform programme.

D. Latin America

Belize: Mapping of agricultural land use and forestry resources by remote sensing;

Ecuador: Operational monitoring of land use in the Amazon region;

Brazil: Strengthening the remote sensing and GIS Centre in the San Francisco Valley Water Development Authority.

E. Europe

Poland: Project on assessment of grassland productivity in Poland.

Concerning monitoring of the Earth's environment (paragraph 300 of the UNISPACE 82 report)

Although FAO was not mentioned in paragraph 300, it is considered appropriate to report on its activities relating to environmental monitoring by satellites to improve inputs to food security and desert locust control operations at the regional and national levels.

Since August 1988, the FAO Remote Sensing Centre has been operationally monitoring precipitation and vegetation in Africa based on semi-automatic processing of image data recorded by the environmental satellites Meteosat and NOAA. Development of this dedicated system for ARTEMIS was the result of close co-operation between FAO and the National Aerospace Laboratory of the Netherlands (prime contractor), the Earth Resources Branch of the National Aeronautics and Space Administration (NASA) (United States of America), Goddard Space Flight Center (NOAA-AVHRR data processing into vegetation index products), the universities of Reading and Bristol in the United Kingdom of Great Britain and Northern Ireland (Meteosat data processing into precipitation assessment products) and various other research groups.

The main users of ARTEMIS precipitation and vegetation-index estimates are the FAO Global Information and Early Warning System (GIEWS) on Food and Agriculture, the FAO Emergency Centre for Locust Operations (ECLO) and regional and national early warning systems on food security in Africa.

During the last year, two major ARTEMIS-related developments were initiated:

(a) Development, in close co-operation with the main user (GIEWS), of new techniques for improved early identification of areas threatened by agricultural drought based on integration of satellite-based ARTEMIS products with field agrometeorological data: this had been preceded by a study of information requirements of GIEWS. These new techniques will be determined by user needs, rather than by technology. The Advanced Resource Technology Programme of the College of Agriculture, University of Arizona, United States, has been contracted to assist with the development of the new integrated techniques;

(b) Co-operating with the European Space Agency on development of a dedicated satellite telecommunication system, DIANA, for real-time transmission of ARTEMIS products from FAO to their users in Africa.

To summarize, the UNISPACE 82 Conference has provided the basic overall framework for focusing the FAO remote sensing activities. An important contribution towards implementing the UNISPACE 82 recommendations has been made by the annual United Nations Inter-Agency Meetings on Outer Space Activities. Since 1982 these meetings have included the review of implementation of the UNISPACE 82 recommendations on their agenda. FAO was pleased to host the 1990 Inter-Agency

meeting, which included extensive discussion of the UNISPACE 82 recommendations and co-operation within the United Nations system on their implementation.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

[Original: French]

Concerning the recommendation for studies on the use of direct broadcasting satellites for education (A/CONF.101/10, paragraph 249 of the UNISPACE 82 report)

UNESCO has published a study entitled Satellites for Education and Development which was transmitted to the Outer Space Affairs Division of the United Nations. Two other studies have been published in which mention is made of space communication: No. 101, Communication, Technology and Development (1988) and No. 105, Les nouvelles technologies de communication: orientation de la recherche (1990).

A report will be published on the regional seminar on distance education in Africa, held at Arusha (United Republic of Tanzania) from 24 to 29 September 1990. The report deals, inter alia, with distance education by satellite.

Concerning the recommendation for studies on communication for development (paragraph 148 of the UNISPACE 82 report)

It should be pointed out that the RASCOM (Regional African Satellite Communication System) feasibility study is in line with the recommendations addressed to the specialized agencies of the United Nations system.

Of course, UNESCO takes part in the co-ordination meetings on outer space activities within the United Nations system, providing an annual update of its programme and activities.

In the science area, the Organization is engaged in the following activities: organization of short- and long-term courses in remote sensing, seminars for decision makers, preparation of distance education programmes and implementation of technical assistance and research projects in the areas of hydrology, ecology, oceanography and geology.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

[Original: English]

FUTURE AIR NAVIGATION SYSTEMS/AERONAUTICAL MOBILE-SATELLITE SERVICE

The International Civil Aviation Organization (ICAO) established in 1983 a special committee of the Council called Future Air Navigation Systems (FANS),

"to study technical, operational, institutional and economic questions, including cost/benefit effects, relating to future potential air navigation systems; to identify and assess new concepts and new technology, including satellite technology, which may have future benefits for the development of international civil aviation including the likely implications they would have for users and providers of such systems; and to make recommendations thereon for an overall long-term projection for the co-ordinated evolutionary development of air navigation for international civil aviation over a period of the order of twenty-five years."

The committee completed its task at the fourth meeting, held in May 1988. A comprehensive assessment and analysis of the characteristics and of the capabilities of the present air navigation systems and of their implementations in different parts of the world ascertained that the shortcomings of the present communications, navigation and surveillance (CNS) system amount to essentially three factors:

(a) Propagation limitations of current line-of-sight systems and/or accuracy and reliability limitations imposed by the variability of propagation characteristics of other systems;

(b) Difficulty, caused by a variety of reasons, of implementing present CNS systems and operating them in a consistent manner in large parts of the world; and

(c) The limitations of voice communications and the lack of digital air-ground data interchange systems to support modern automated systems in the air and on the ground.

Most of the above limitations are intrinsic to the systems themselves, although their effects are not the same for every part of the world. As a prime objective, the future air navigation system should not only resolve the shortcomings of the present air navigation system but also take care of future requirements. To this effect, it should provide for:

(a) Global communication, navigation and surveillance coverage from ground to very high altitude;

(b) Digital data interchange capability between air-ground systems to fully exploit the automated capabilities of both;

(c) Navigation/approach service for runways and other landing areas which need not be equipped with precision landing aids; and

(d) Sufficient flexibility to adapt to the different air traffic conditions around the world without undue cost/benefit penalties.

The exploitation of satellite technology was singled out as the most appropriate solution to overcome the shortcomings of the present air navigation system and to fulfil the needs and requirements for the foreseeable future on a global basis.

As a result of the work of the first committee of FANS, the Aeronautical Mobile-Satellite Service (AMSS) Panel was formed to develop Standards and Recommended Practices (SARPs) and guidance material for satellite communication systems to be used for aeronautical mobile communications services. While this service is primarily for safety services, the provision of non-safety services was included to simplify the avionics and its cost and to help in sharing the cost of equipping aircraft. Furthermore, its inclusion will facilitate the efficient use of the already scarce frequency spectrum and facilitate operational co-ordination.

Tests and experiments

A number of ICAO member States and international organizations are conducting experiments to assess different technical aspects of the future satellite-based CNS system and are planning implementation of services to be provided. These various field trials and demonstrations have already produced interesting results, which indicate that significant benefits could be achieved.

Canada has started automatic dependent surveillance (ADS) experiments using the VHF air-ground data link network implemented by Air Canada. Data elements transmitted include latitude, longitude, altitude, wind speed, wind direction, temperature, next waypoint and secondary surveillance radar (SSR) transponder code. The data are received and processed at Transport Canada's Technical System Centre. The purpose of the experiment is to gain technical and operational experience with ADS. It may also be possible to better characterize the performance of inertial reference systems through mathematical comparison of ADS data and SSR data.

Japan is pursuing three different experimental programmes for aeronautical satellite communications using Engineering Test Satellite V (ETS-V) and International Maritime Satellite Organization (INMARSAT) facilities. These programmes involve air traffic control (ATC) experiments for ADS and ATC communications and aeronautical passenger communication (APC) experiments for voice/data communications and facsimile.

On 24 October 1988, Spanish civil aviation authorities, using an experimental satellite system, succeeded in controlling a Jetstream aircraft which departed from Biggin Hill (United Kingdom of Great Britain and Northern Ireland) and landed at the Madrid-Barajas airport (Spain), thus becoming the first flight in the history of civil aviation to be controlled via satellite data link.

The United Kingdom Civil Aviation Authority (CAA) has been participating in a European Space Agency (ESA) programme of work called PROSAT (promotional satellite), the overall aim of which is to promote the use of satellites for mobile communication. The PROSAT programme has resulted in a co-operative programme of experiments in Europe involving satellite communication for land, maritime and aeronautical mobile units. Although PROSAT provides for the transfer of both voice and digital data, the collaborating ATC experimenters (United Kingdom CAA, the European Organisation for the Safety of Air Navigation (EUROCONTROL) and the Spanish civil aviation agency) are only making use of the low rate data service known as PRODAT.

The United Kingdom's PRODAT experiments are being undertaken in two phases. The first phase is a technical evaluation and data collection which takes place during the communications experiments using trial and commercial aircraft.

The second phase will be a programme of ATC simulations drawing on the data collected during the first phase. During the data collection all messages sent to, and received from, the network management system (NMS) are recorded with any message delivery failure reports. This recorded information will be used for the evaluation of various communications system performance parameters and is a source of authentic data for investigations in the second phase of ATC applications envisaged for aeronautical data links. Specific applications to be investigated are ADS, waypoint verification, ATC/pilot communication, ground data base access and meteorological data reporting.

United Kingdom CAA also conducted an assessment of four voice coders, each using different algorithms operating at 8 or 9.6 kbits/s. The four coders assessed were those identified by the Airlines Electronic Engineering Committee, one of which will be chosen as an airline industry standard.

The assessment of the voice coders, using conversation tests, was undertaken at CAA's Air Traffic Control Evaluation Unit using experienced air traffic control personnel interacting with a simple ATC simulation including a "pseudo-pilot" position. Although one of the first applications of satellite voice communication in support of ATC is likely to be in low-density airspace such as oceanic areas, the assessment was undertaken using a simulation of a high-density airspace to increase the voice communication workload.

The objectives of the assessment were to evaluate the acceptability of voice-coded speech in an ATC environment in terms of intelligibility and transmission delays, using both objective and subjective information; to evaluate the relative performance of the four voice coder algorithms; and to evaluate the performance of all the voice coders in a full duplex mode of operation and at least one voice coder in both half and full duplex mode.

Efforts are now under way by a number of manufacturers of business aircraft (essentially under 34,000 kg, gross take-off weight) and avionics manufacturers to develop the changes and additions necessary to accommodate satellite communications and navigation at the earliest possible date. Structural difficulties arise when attempting to fit current 12 dBi antenna designs to the typically smaller airframes of business aircraft. This problem is further exacerbated by the need to accommodate the beam steering and the various amplifiers in very close proximity to large high-gain antennas.

Activities currently under way

The international INMARSAT system has been designated as the core satellite communications system in the Union of Soviet Socialist Republics for the development of aircraft and ground aeronautical satellite communication facilities. The ground satellite communication centres are being established in the same locations as the INMARSAT satellite communications system centres, located

in the city of Odessa (service area - the Atlantic Ocean and the Indian Ocean) and the city of Nakhodka (service area - the Pacific Ocean). The timetable for introducing the aeronautical satellite communication facilities into operation in the Soviet Union basically coincides with the timetable for the development of the second-generation satellites of the INMARSAT system.

In Canada, a mobile-satellite communications (MSAT) system is being implemented by Telesat Mobile Inc. The service requirements for Canada have been divided into four categories: (a) the mobile radio service, a circuit-switched voice and data private network service; (b) the mobile telephone service, a circuit-switched voice and data private network service with interconnection to the public-switched telephone network; (c) the mobile data service, a packet-switched data service; and (d) the aeronautical mobile services, a service compatible with the international standard.

In May 1989, the Société Internationale de Télécommunications Aéronautiques (SITA) and three public telecommunications carriers, France Telecom, OTC Ltd. (Australia) and Teleglobe Canada Inc., entered into formal agreement for the joint development and provision of AMS(R)S services in conformity with aeronautical standards. The group will initially make use of INMARSAT space segment, but could use other suitable alternate or complementary space segments in the future. The deployment of six full service (data and voice) ground Earth stations (GESs) will begin during the fourth quarter of 1990, with worldwide coverage expected before year end. When the deployment is completed, access to each ocean region will be provided redundantly by two ground Earth stations. The full-service GESs are currently being developed on the basis of existing aeronautical standards and will be initially able to provide aeronautical operating communications (AOC), aeronautical administrative communications (AAC) and APC communications. As standards evolve, GESs will be upgraded to serve all needs of the aeronautical community.

In a similar manner, Aeronautical Radio, Inc. (ARINC) has arrangements with British Telecom, the Communication Satellite Corporation (COMSAT) (United States) and the Norwegian Telecommunications Administration for the provision of aeronautical mobile-satellite services. ARINC and SITA also have a joint venture which covers a broad range of co-operative activities aiming at ensuring full compatibility of end-to-end AMS(R)S services developed by the two organizations, continuity of service by reciprocal exchange of services for backup purposes and long-term availability of necessary ground and space segment resources to meet the demand of the community.

The United States Federal Aviation Administration (FAA) is pursuing improvements in oceanic air traffic control. In this effort, FAA is implementing the oceanic display and planning system (ODAPS), an ATC automation system, in the Oakland, California, and New York Oceanic Control Centers. An initial automatic dependent surveillance functional implementation is also being pursued. The ADS function will be implemented in a stepped-phase fashion in order to meet a timely schedule for early operational service. Step I will allow one-way communication only (position reports from the aircraft). This is expected to minimize changes to the ATC automation system and ATC procedures. Step II is planned to provide a

two-way communication capability, including dynamic control of ADS and direct pilot-controller data link communication. Relative to step I, this will necessarily require additional hardware and more extensive software and ATC procedures development. A System Requirements Team, composed of FAA oceanic ATC controllers, international representatives, technical support and other representatives, is developing the requirements for step II.

ICAO's future activities

After the FANS Committee defined the global CNS system concept, the ICAO Council saw the need for a new special committee to proceed with the second phase of the project, monitoring and co-ordination of development and implementation planning, including the transition phase for the future air navigation system.

The FANS (Phase II) Committee met in May 1990 and has already set the groundwork for the establishment of two databases to assist in the monitoring and planning functions. One will consist of tests and experiments being carried out around the world and the other will involve implementation activities.

In addition, the committee has also developed a set of scenarios representing different implementation approaches to assist in the development of guidelines on necessary institutional arrangements to support a global CNS system.

ICAO is planning to hold an air navigation conference at Montreal in September 1991. The purpose of the conference would be to secure global acceptance of the CNS system concept. The work of FANS (II) associated with the implementation planning of the future global CNS system is most critical and complex, since it is a major departure from the conventional air navigation system arrangement. Judging from past experience, ICAO is confident that the new committee will meet its commitment in defining the necessary institutional arrangements to support the future CNS system and that it will develop, in conjunction with the ICAO regional offices, a transition plan that will enable the full realization of the benefits associated with global implementation of the new system.

SATELLITE-AIDED SEARCH AND RESCUE

Various forms of emergency transmitters have been in use for more than 30 years. Before 1982, the essential reliance on overflying aircraft to detect emergency transmissions from a crash site and to alert search and rescue (SAR) authorities meant that coverage was incomplete and sporadic at best. A great number of unintentional activations (false alarms) reduced, and continue to reduce, the effectiveness of the system. SAR authorities have therefore looked for improved techniques to receive alerts and to locate distress situations while minimizing problems caused by false alarms.

One such improvement lies in the use of low, polar-orbiting satellites which are able to monitor the entire Earth systematically. These satellites provide rescue co-ordination centres (RCCs) with a means of distress alerting independent

of air routes or air traffic patterns and have the potential for significantly increasing the accuracy of location information. Further improvement would be the use of distress beacons designed for co-operation with satellites, with the ability to transmit digital data including beacon identity.

In 1979, a memorandum of understanding was signed by agencies in Canada, France and the United States which led to the establishment of an experimental project for exploring the concept of search-and-rescue satellite-aided tracking (SARSAT). Subsequently, the SARSAT partners signed a memorandum of understanding with the Soviet Union, which was engaged in an experimental project with the same objective (COSPAS). The first satellite carrying a search-and-rescue space segment was launched in June 1982. Subsequent launches have ensured that at least four space segments are constantly operational, ensuring a global coverage. On 1 July 1988, the four parties signed the International COSPAS-SARSAT Programme Agreement, with the Secretary-General of the International Civil Aviation Organization as one of the depositaries. The Agreement ensures the availability of the system for a period of 15 years, the Agreement to be extended automatically for successive periods of 5 years.

The COSPAS-SARSAT system consists of the space segment, local user terminals (LUTs) and mission control centres (MCCs). The space segment monitors signals on 121.5 MHz, 243 MHz and 406 MHz. When a distress signal is detected, the space segment will transmit the signal to a LUT which in turn will send incident data to the associated MCC. The MCC will then distribute the data to the appropriate RCC for search-and-rescue action. On the 121.5 and 243 MHz frequencies the system operates in a local mode only, which limits the usefulness of the system to areas where a satellite is within the line of sight of a distress beacon and a LUT simultaneously. First-generation distress beacons operating on 121.5/243 MHz have exhibited a high false alarm rate and low activation reliability, but have also in many cases been vital in alerting and locating a distress site by search-and-rescue forces. However, due to their characteristics and the use of 121.5 MHz for other purposes, detection and location through satellites of distress beacons operating on 121.5 MHz has not always been possible.

On the 406 MHz frequency the system operates in both a local and a global mode, ensuring coverage of the entire Earth. Digital data received from distress beacons operating at 406 MHz are stored on board spacecraft for transmission to any LUT when the satellite comes within line of sight. Digital encoding of the 406 MHz signals permits rapid validation and beacon identification, thereby minimizing false alarms and ensuring rapid alerting and location of the distress site. The location of an emergency transmitter operating at 406 MHz may be pinpointed to within a radius of 5 km, while a transmitter operating on 121.5 MHz can be located to be within a radius of approximately 20 km.

Between September 1982 and December 1989, the COSPAS-SARSAT system has provided assistance in rescuing 1,560 persons in 569 search-and-rescue events. Of these, 852 persons in 365 events (64.1 per cent of the total) were rescued in aviation distress situations. By the end of August 1990, LUTs in 11 countries were in operation. To increase the local coverage of the system, 12 more LUTs are projected in 6 different countries. In addition to the nine MCCs in operation at

present, five more are projected to start operations before the end of 1992. A full complement of space segment is operational, with further launch dates scheduled for February and May 1991, which would increase the overall effectiveness of the system, particularly the global coverage afforded by the 406 MHz system.

Since 1980, ICAO has closely followed the developments related to satellite-aided search and rescue, and status reports have been provided periodically to the ICAO Council and contracting States. In 1989, States and appropriate international organizations were consulted on a future aviation policy in respect of distress beacons, concerning beacon specifications, including frequencies to be used, distress beacon carriage requirements and terminology. The results of the consultation with States reflected strong support for a new generation of aviation distress beacons which were designed for optimum co-operation with the COSPAS-SARSAT system. It was noted that optimum performance of the system would only be possible at 406 MHz, with global coverage being provided at this frequency.

At its 16th meeting of the one hundred thirtieth session (21 June 1990), the ICAO Council approved a policy on future aviation distress beacons with the understanding that further consultations with States may be necessary in the light of experience gained (see appendix below).

APPENDIX

ICAO policy on future aviation distress beacons

The long-term objectives of ICAO in respect of distress beacons are as follows:

(a) All aviation distress beacons should be designed to co-operate with the COSPAS-SARSAT system in alerting and locating distress sites, preferably including identification of the beacon;

(b) In order to obtain optimum benefit from the COSPAS-SARSAT system, 406 MHz should become the primary frequency for alerting, identification and location of aviation distress sites;

(c) The 121.5 MHz frequency should continue for the foreseeable future to fulfil a role in distress beacons for overflight monitoring and homing, and should continue to be available for voice communications.

In order to accomplish the foregoing long-term objectives, the following measures should be taken:

(a) Specifications for aviation distress beacons should be developed for inclusion in annex 10, which will provide a choice between:

(1) Distress beacons operating simultaneously at 406 MHz and 121.5 MHz (121.5 MHz being provided for overflight monitoring and homing purposes at a lower power level in the same beacons, or by a separate beacon); and

(2) Improved distress beacons operating at 121.5/243 MHz;

(b) The use of first-generation distress beacons (operating at 121.5/243 MHz) should gradually be phased out through States' requirements for the use of distress beacons which meet the annex 10 specifications in all new installations of distress beacons;

(c) The use of aviation distress beacons operating at 406 MHz (and simultaneously at 121.5 MHz) should be encouraged;

(d) Although at present no termination date is envisaged for distress beacons operating at 121.5/243 MHz, in the light of experience it may become desirable to require the use of distress beacons operating simultaneously at 406/121.5 MHz or at 406 MHz alone. Such a requirement is not expected until after the year 2000.

World area forecast system

The world area forecast system (WAFS) was designed in the early 1980s to provide civil aviation with high-quality forecasts of en-route weather conditions concerning upper winds, upper air temperatures and significant weather, contributing thus to its safety, regularity and efficiency.

It was understood at that time that the global character of the system and high quality of WAFS products, along with the high efficiency of the system, could be achieved only when the most modern technologies, both for processing products and their distribution to users, in particular to airline operators, flight crew members, meteorological services, etc., were used within the highly centralized system.

The telecommunication support for the final phase of WAFS was therefore envisaged and recommended by the ICAO Communications/Meteorology (COM/MET) Divisional Meeting, 1982, to benefit from satellite telecommunications technologies primarily from point-to-multi-point broadcast of WAFS products in digital grid point and pictorial formats via satellite. Two world area forecast centres (WAFCs) (London, Washington) were expected eventually to uplink global WAFS products to suitable satellites, to be downlinked direct to users.

Recent rapid developments in satellite data telecommunication technologies have thus opened great possibilities to all users to receive high-quality WAFS data from satellite to small dish antennas forming a part of low-cost micro-Earth stations.

The planning for implementation of the final phase of WAFS in terms of the dissemination of WAFS products by satellite point-to-multi-point satellite broadcast was initiated by a decision of the Council in 1982, assigning the ICAO

Aeronautical Fixed Service Systems Planning for Data Interchange Panel to conduct a study on the refinement of the satellite broadcast concept for dissemination of WAFS products. The study was completed in 1989, endorsing the concept of satellite broadcast for dissemination of WAFS products not only in the final phase of the system but also in the current transition from the initial phase of WAFS to the final phase of WAFS. The INTELNET I satellite broadcast service of the International Telecommunications Satellite Organization (INTELSAT) was indicated in general as being capable of providing global coverage for the dissemination of WAFS data. Before WAFS products are available in the WAFCs in digital grid point form, the advantages of dissemination of WAFS in digital fascimile format could be taken to meet requirements for WAFS products by regional area forecast centres and users.

Similar conceptual decisions regarding planning for telecommunication support for the dissemination of WAFS products have been successively made by the appropriate regional planning bodies in other ICAO regions: Middle East region, 1983; European and African regions, 1988. Furthermore, in addition to the same conceptual decisions made for the Caribbean and South American regions, 1989 and the Asia/Pacific regions in 1990, the concrete steps towards the implementation of satellite broadcast to disseminate WAFS data were taken when the United States announced its intention to uplink WAFS data to a suitable satellite, likely using INTELSAT services, for the benefit of users in those two ICAO regions. The United States is scheduled to begin satellite broadcast for the Caribbean and South American regions in 1992 and for the Asia and Pacific regions in 1993. Another important development along these lines has recently been approved by the ICAO European Air Navigation Planning Group. The group accepted the Satellite Distribution System (SADIS) designed to meet requirements for receiving WAFS products in Europe, but also indicated its potential to be expanded in the future to serve States in Africa.

An ICAO/World Meteorological Organization (WMO) study of the feasibility of the joint use of satellite dissemination is being pursued by the two organizations as a matter of high interest to their members in order to achieve more cost-effective solutions in planning and operations of satellite communications systems involved in the exchange of meteorological information.

The transition to the final phase of WAFS, including the telecommunication support of the transition, appeared as an agenda item of the ICAO Communications/Meteorology/Operations (COM/MET/OPS) divisional meeting (September 1990). The set of updated provisions relating to WAFS developed by the meeting, together with the technical provisions relating to international point-to-multi-point telecommunication service via satellite, developed within ICAO earlier, provides for the full use of satellite communication technology within current and future phases of WAFS.

In addition, satellite telecommunications will indeed contribute in the near future to increase the quality of exchange of other operational meteorological data such as aerodrome reports and forecasts, air reports, information on hazardous weather phenomena, etc., primarily in areas where terrestrial telecommunications are not adequate to meet requirements of international air navigation.

INTERNATIONAL TELECOMMUNICATION UNION

[Original: English]

The International Telecommunication Union (ITU) has since the late 1950s continued to carry out studies on optimum allocation of radio frequency bands for various services, including the criteria for sharing and, in general, the use of the geostationary orbit (see A/CONF.101/10, paras. 68 and 69). Any changes which were found necessary were discussed and adopted during the relevant World Administrative Radio Conferences (WARC). The WARC planned for 1992 will introduce new changes in the allocation of frequency bands to some services.

It is to be noted that such studies are not merely desirable but also essential in optimizing the efficiency of the radio-frequency spectrum and geostationary orbit utilization. The studies remain a continuing activity of ITU in fulfilment of its mandates regarding the radio-frequency spectrum and the geostationary orbit.

ITU has also undertaken various studies regarding the developmental aspects of telecommunications (ibid., para. 148). For example, ITU, together with several other organizations, is currently finalizing a study on the Regional African Satellite Communication System (RASCOM) for the development of Africa, which is specifically conceived to increase the penetration of telecommunication services into the rural areas of Africa, where some 80 per cent of the population lives. The application of such services for education, agriculture, public information, public telecommunication, etc., will enhance rural development and intra-continental socio-economic integration and growth.

Taking measures to avoid radio frequency interference (ibid., para. 189) is a specific mandate and continuous activity of ITU. As new technologies emerge and new services are introduced ITU continues to take measures necessary to ensure that radio frequency interference is avoided.

The question of removing expired satellites from the geostationary orbit (ibid., para. 283) has been further considered at the seventeenth Plenary Assembly of the International Radio Consultative Committee, Düsseldorf, Germany, 1990, where an updated report on physical interference in the geostationary orbit was approved. Further studies remain to be done before a definite recommendation can be adopted. An Administration can, however, bring this matter to a future competent WARC.

The encouraging achievements of the World Administrative Radio Conference on the use of the geostationary orbit held in 1985 (WARC-ORB (85)), and more so the Conference held on the same subject in 1988 (WARC-ORB (88)), meet the requirements of the recommendations in paragraphs 284 and 286 of the UNISPACE 82 report.

WORLD METEOROLOGICAL ORGANIZATION

[Original: English]

RECOMMENDATIONS ADDRESSED TO SPECIALIZED AGENCIES

Concerning the recommendation that the World Meteorological Organization should be encouraged to continue its examination of the feasibility of setting up regional or international centres for meteorological data reception and analysis (A/CONF.101/10, paragraph 89 of the UNISPACE 82 report)

The deliberations of UNISPACE 82 noted that to extract the full value of meteorological information from satellite data required sophisticated data pre-processing, analysis and modelling. Therefore, UNISPACE 82 recommended the establishment of regional or international centres for meteorological data reception and analysis. UNISPACE 82 also suggested that, prior to establishing these centres, a telecommunication analysis be conducted to determine what would be the impact on a data distribution system.

Due to the fact that the issue of data utilization is of utmost importance, the World Meteorological Organization (WMO) actively participated in several upgrade programmes, especially for the World Weather Watch (WWW) programme. Concurrent to these upgrades, and during the time period since UNISPACE 82, technology advances have solved data utilization issues. Telecommunication analyses indicated that the costs for regional and international reception centres that would distribute satellite data to all Member States would be exorbitant. Fortunately, the unit costs for reception of the full data streams have fallen insomuch that all national meteorological services and many private enterprises can afford direct reception equipment and obviate the need to build large redistribution systems. For those organizations that cannot afford the inexpensive receivers, the satellite operators are now maintaining archival services whereby anyone can obtain the full digital information. The recommendation of UNISPACE 82, for this application, can be considered accomplished.

Concerning the recommendation that all countries should continue to have free access to meteorological data and WMO should be encouraged to ensure optimal use of space techniques, in particular in the related aspects of facilities for data reception and processing, data analysis and dissemination; and that WMO should also envisage undertaking a study concerning the possibility of setting up an international structure providing access to satellite meteorological data (paragraph 224 of the UNISPACE 82 report)

The basic precept of international data exchange for WMO has been free and open. This concept was again reaffirmed in the most recent meeting of the Executive Council. With regard to an international structure providing access to satellite meteorological data, the Commission for Basic Systems, one of the seven technical commissions of WMO, has developed both a guide and manual for the global observing system (GOS). Those documents contain descriptions of the space-based portion of GOS. Another advisory body to the Executive Council is the Executive Council Panel of Experts on Satellites, which reviews and makes recommendations for improving the international structure.

Concerning the recommendation that WMO should continue to actively promote international co-operation in space meteorology, encourage compatibility and complementarity between different systems and take all necessary steps to ensure continuity of data availability to all countries (paragraph 264 of the UNISPACE 82 report)

As noted above, WMO has reaffirmed its commitment to free and open exchange of data.

RECOMMENDATIONS ADDRESSED TO OTHER INTERNATIONAL ORGANIZATIONS

Paragraph 176 of the UNISPACE 82 report

Access to data from operational meteorological satellites is free, and because many countries have become dependent upon this system it is necessary to ensure the continuation and intensification of such services.

WMO functions under the fundamental concept of free and open data exchange. At the most recent meeting of the WMO Executive Council, they reaffirmed their commitment to the free and unrestricted international exchange of basic data and products, as defined in the World Weather Watch (WWW) programme. For the purposes of UNISPACE 82, WMO will continue this policy, and therefore the recommendation should be considered satisfied.

INTERNATIONAL MARITIME ORGANIZATION

[Original: English]

With respect to technical assistance by the United Nations system (para. 157 of the UNISPACE 82 report), the International Maritime Organization (IMO), in co-operation with the International Maritime Satellite Organization (INMARSAT) and COSPAS-SARSAT, has organized a number of global and regional seminars to explain the implications of the global maritime distress and safety system (GMDSS).

With respect to international co-operation in satellite-based search and rescue (paras. 157 and 185 of the UNISPACE 82 report), IMO, in co-operation with the International Telecommunication Union (ITU) and the International Radio Consultative Committee (CCIR), INMARSAT and COSPAS-SARSAT, has developed the global maritime distress and safety system, a major element of which is satellite communications. GMDSS is being implemented through amendments to the International Convention for the Safety of Life at Sea (SOLAS) 1974 and the ITU Radio Regulations and provides for the communication needs of the maritime search-and-rescue plan being developed by IMO. GMDSS is intended to be used by ships of all sizes and types, wherever they operate. Small, relatively inexpensive ship-borne terminals, for use worldwide in GMDSS, include INMARSAT Standard-C ship Earth stations (SES) and satellite emergency position-indicating radio beacons (EPIRBs) operating through the COSPAS-SARSAT polar orbiting satellite system and the INMARSAT geostationary satellite service. The INMARSAT enhanced group call system

(SafetyNET) will also be used for broadcasts of maritime safety information and can be received by the Standard-C (SES) or a dedicated receiver.

WORLD INTELLECTUAL PROPERTY ORGANIZATION

[Original: English]

Concerning the recommendation that the United Nations, in association with concerned specialized agencies, should examine all the global implications, including the legal implications, of new space developments (paragraph 312 of the UNISPACE 82 report)

The promotion of the Convention relating to the distribution of programme-carrying signals transmitted by satellite (1974 Brussels Convention) will continue. Also, the United Nations Educational, Scientific and Cultural Organization (UNESCO), in collaboration with the World Intellectual Property Organization (WIPO) and the International Labour Organisation (ILO) will continue to study the different aspects of the problems that other conventions, e.g., the Rome Convention, raise in relation to the law and practice concerning cable and satellite transmissions.

WIPO will continue to study various aspects of copyright law that relate to the transmission of programmes by satellite, in particular in the preparation of a model law on copyright. Furthermore, in the draft programme and budget for the 1990-1991 biennium, it is envisaged that a number of copyright questions relating to, inter alia, satellite transmissions, will be dealt with in the context of the preparation of a possible protocol to the Berne Convention for the Protection of Literary and Artistic Works.

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COMMITTEE ON THE PEACEFUL USES OF
OUTER SPACE

HIGHLIGHTS IN SPACE TECHNOLOGY AND APPLICATIONS OF 1990

Report submitted by the International Astronautical Federation

Note by the Secretariat

Annexed herewith is a report on the highlights in space technology and applications of 1990 submitted by the International Astronautical Federation (IAF) in accordance with the request of the Scientific and Technical Sub-Committee for the submission of annual reports by IAF on scientific and technological developments in the exploration and peaceful uses of outer space.

The report was prepared by Dr. Dale Fester and Dr. Lubos Perek, Co-Chairmen of the International Programme Committee for the 41st IAF Congress, with the assistance of Dr. Jerry Grey, former President of the Federation, and was approved by Dr. Alvaro Azcarraga, the current President of IAF. The report is being circulated, as received, only in the language of its submisssion (English).

Annex

HIGHLIGHTS IN SPACE TECHNOLOGY AND APPLICATIONS 1990

Prepared by the

INTERNATIONAL ASTRONAUTICAL FEDERATION (IAF)

for the

Scientific and Technical Subcommittee
Committee on the Peaceful Uses of Outer Space
UNITED NATIONS

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I. SUMMARY

The highlights in space technology and applications in 1990 were the acceleration in development of mobile satellite communications services; the entry of small satellites for use in communications, Earth observations, position location and navigation, and scientific research; the maturation of radio-broadcast services by satellite; initiation of the Earth Observing System, the main element in Mission to Planet Earth, whose goal is to collect the data needed to make long-term environmental policy decisions; establishment of Mission to Planet Earth as the main focus for the International Space Year; launch and first image generation by the Hubble Telescope; launch of the Ulysses solar research spacecraft; growth of activity in formulating mission architectures and technologies for returning to the Moon and human exploration of Mars; the development of technologies for space plane launchers; recognition of the need for early action to alleviate growing concerns about space debris; and progress by the United Nations toward a policy for the use of nuclear power systems in space.

The government-supported space programs of all the major spacefaring nations have been adjusted to deal with ever more stringent budgetary constraints, resulting in the "stretching" of many projects and the elimination of some. This limitation was countered by the proliferation of mergers and consortia of nongovernment corporations, particularly in Europe and the U.S., to develop and market space products and services, and by a major reorientation of many programs and launch operations that were formerly supported by governments to commercial financing, particularly in the Soviet Union, China, and Eastern Europe.

II. SPACE TRANSPORTATION

A. Current Launch Activities

(1) Soviet Union

The Soviet Union carried out a large number of launches using its extensive stable of vehicles. Fewer flights were made this year than last, signaling higher performance and longer lifetimes of Soviet spacecraft.

A Meteor 3 spacecraft will be launched by the Soviet Union to carry a U.S. NASA Total Ozone Mapping Spectrometer (TOMS) in 1991. The Soviet-U.S. launch agreement was signed on 25 July.

The Progress M cargo carrier for Mir has been equipped with the capability to return material from Mir to Earth. The New version, Progress M5, was launched 27 September. It can eject a 150-kg parachute-deployed capsule containing crystals and other products manufactured aboard Mir during the vehicle's reentry.

The Zenit launcher suffered its first failure in 20 flights during an attempted launch on 4 October. The vehicle was destroyed several seconds after leaving the Baikonur cosmodrome. The failure is not expected to affect Zenit's roles as the primary launcher for the Australian Cape York site or as the Energiya booster.

An as-yet unspecified Soviet vehicle will be used to launch the U.S. Space Sciences Institute's privately financed 130-kg Lunar Prospector spacecraft in 1992. The launch agreement (with the Scientific Production Association Energiya) was signed in September.

(2) United States

All four of the major U.S. launch vehicles were in operation this year. The Shuttle flew three missions before being grounded by a series of hydrogen leaks in the summer, but then flew two more subsequently; the second Titan 4 flew successfully and Titan 3 launched an Intelsat 6 in June after having failed to deliver one into its proper orbit in February; the first commercial Atlas launched a NASA research payload into space in July; and Delta II launched several Navstar Global Positioning Satellites, rendering the system operational, Delta also launched several commercial payloads, marking its 200th flight when it launched the first Inmarsat 2 on 30 October.

On 5 April Orbital Sciences Corporation launched its Pegasus vehicle from under the wing of a B-52 aircraft, placing two satellites into a low polar orbit. The three-stage rocket, whose first stage is equipped with small delta wings, was the first new expendable orbital launcher to be developed successfully by the U.S. in the past 20 years. Its 190-kg payload consisted of a small U.S. Navy communications satellite, a NASA research satellite that, on 15 April, conducted magnetic field experiments by releasing a multicolored cloud of barium over Canada, and the Pegasus vehicle electronics package. Orbital Sciences subsidiary Space Data Corporation also received contracts to launch 12 suborbital payloads for the U.S. Defense Department beginning in February 1991 and lasting 2-1/2 years.

On 11 April a U.S. Air Force Atlas E combined with a Scout-Altair upper stage launched three small scientific satellites each weighing between 55 and 70 kg, into a 750-km polar orbit. The three payloads, collectively called "Stacksat", were a Polar Orbiting Geomagnetic Survey to update the Earth's magnetic field, a Transceiver Experiment to study radio-disrupting irregularities in the upper atmosphere, and a Selective Communications Experiment, to evaluate different frequencies for their susceptibility to interference.

The second Titan 4 successfully launched a military payload on 8 June. Titan 4 is the largest U.S. expendable launcher, able to lift over 18 tonnes to low Earth orbit.

The first commercial Atlas flight took place on 25 July, placing a NASA research payload, the Combined Release and Radiation Effects Satellite (CRRES), into a geosynchronous transfer orbit. In September the satellite released lithium, barium, and other chemical clouds over the Pacific Ocean to study the Earth's electric and magnetic fields. The next commercial Atlas launch, early in 1991, will orbit one of the five new Eutelsat-2 spacecraft. General Dynamics also signed a launch contract on 31 August for the 1170-kg Italian X-Ray Astronomy Satellite, scheduled to fly in 1994.

(3) Europe

Ariane 35 launched the first group of small payloads on 21 January (along with SPOT-2) from its new payload housing platform, Ariane Structure for Auxiliary Payloads. The six "microsats" launched were 40-kg UoSats D and E, for the UK's University of Surrey, and four 12-kg OSCAR amateur radio satellites for the U.S. Radio Amateur Satellite Corporation. Arianespace also announced a new capability that will allow payloads in the 400-800 kg range to be launched as "companion" payloads. This Spelda Dedicated Satellite (SDS) payload category is expected to be available in 1992.

Recovery from the Ariane 44L launch failure on 22 February, in which two Japanese communications satellites were lost (NHK's direct-broadcast satellite BS-2X and Space Communications Corporation's Superbird B), was marked by the successful flights on 24 July, 30 August, and 12 October. The February launch failure was eventually traced to improper maintenance procedures which allowed a piece of cloth to be left in the first-stage Viking engine water supply system. The 24 July flight, also an Ariane 44L, successfully placed in orbit the German DFS Kopernikus 2, weighing 1418 kg, and the French TDF-2, weighing 2096 kg. DFS-2 is a television, radio, and telephone communications spacecraft; TDF-2 is a direct-broadcast satellite. The 30 August launch, this time an Ariane 44LP, carried the 1430-kg British Skynet 4C military communications satellite and the first 1878-kg Eutelsat 2 (Eutelsat 2-F1; see below). The 12 October 44L flight launched two U.S. Hughes satellites, Galaxy 6 and SBS 6. Galaxy 6, weighing 1212 kg, will service cable television networks; SBS-6, a 2478-kg Ku-band satellite, is aimed at the small-terminal television broadcast relay market.

Arianespace won the contract to launch two communications satellites for Brazil, the first of which, Brazilsat B-1, is scheduled to fly in April 1991.

(4) Japan

Japan's first launch of three satellites simultaneously took place on 7 February, when an H-1 rocket launched MOS-1B, a 740-kg Marine Observation Satellite.

A 77-company consortium Rocket Systems, Inc., was formed on 5 July to build, market, and operate the H-2 vehicle when its development is complete. Current problems with the launch vehicle's first-stage LE-7 hydrogen-oxygen engine appear to have delayed the H-2's first flight until 1993.

Development problems this year with the H-2's first-stage cryogenic engine (see below) are expected to delay the vehicle's first launch until 1993.

(5) China

On 4 February China launched its fifth domestic communications satellite, DFH-2A, on a Long March 3 rocket. The first flight of the new Long March (CZ) 2E took place successfully on 16 July, placing a small (50-kg) Pakistani payload, Badar-1, in orbit, along with a mockup of the Aussat-B communications satellite it is scheduled to launch next year. The CZ-2E's four strap-on boosters give it a payload capacity of about 8800 kg to low Earth orbit.

(6) India

Although no launches by an Indian vehicle took place this year, there was significant activity in preparing the Augmented Satellite Launch Vehicle (ASLV) for its third test flight, of a 150-kg Stretched Rohini Satellite, in 1991. Testing and assembly also continued on the 1000-kg-class Polar Satellite Launch Vehicle (PLSV), also scheduled for a 1991 launch, and configuration studies were completed on a Geostationary Launch Vehicle (GSLV), which will include an indigenous cryogenic upper stage.

(7) Other Launch Vehicle Activity

Israel launched Offeq 2 on 2 April into an elliptical retrograde orbit with an inclination of 143 degrees. The scientific payload weighed 160 kg; it reentered the atmosphere and was destroyed later in the year. Israel's next satellite, the first to carry scientific instruments on board, will be launched by the Shavit vehicle in 1991 or 1992.

Australian Launch Vehicles Pty. Ltd. was founded to meet the growing need for small-payload launchers (see below). The new company hopes to launch its first two-stage, solid-propellant rocket for two Australian government missions in late 1992.

B. Development Activity

The U.S. canceled its Orbital Maneuvering Vehicle, which was to have supported both Shuttle and Freedom operations, but still

plans to proceed with development of an Assured Crew Return Vehicle (ACRV) for use with Freedom. Although final definition decisions have not yet been made, it is likely to carry four to eight crew members and be designed as a simple reentry body similar to the Apollo capsule.

The U.S. is still considering whether or not to build a cargo derivative of the Shuttle, called Shuttle-C, to support Freedom deployment, logistics, and early operational phases. Replacing the Shuttle's winged orbiter with an expendable cargo module would more than double the Shuttle's present payload capability (about 22,000 kg), but would cost about $1.5 billion to develop. Continued studies were approved for 1991, but no decision was made to proceed with development.

Rockwell International joined NASA in financing the Extended Duration Orbiter (EDO), which will extend Shuttle stay-time in orbit from its present maximum of about ten days to as long as 16 days by 1994. The EDO kit includes equipment to extend fuel-cell operating time, a new crew lavatory, a cabin atmosphere recycling system, and additional storage space.

The U.S. decided to continue research and development of propulsion technology for its Advanced Launch System (ALS), to be designed as a highly reliable, low-cost family of expendable launchers, but canceled plans for development of an ALS vehicle. The U.S. Air Force subsequently endorsed plans to develop an ALS-derived family of vehicles able to carry payloads ranging from 15 to 55 tonnes to low Earth orbit. Coordination of this vehicle with NASA's abovementioned Shuttle-C is being explored. An industry team consisting of former competitors Aerojet, Rocketdyne, and Pratt & Whitney selected a relatively simple gas-generator design for the 260-kg thrust hydrogen-oxygen ALS engine.

The U.S. Navy has begun preliminary work on an even simpler launcher, the Sea Launch and Recovery (SEALAR) vehicle, whose goal is to launch up to 4,000 kg to low Earth orbit at a cost of US$ 1200 per kg. SEALAR is a 2-stage pressure-fed liquid-propellant rocket launched from a vertical floating position in the sea. The first stage is recovered after falling back into the sea. Preliminary drop tests of a dummy prototype were conducted this year.

The U.S. National Aerospace Plane Program (NASP), whose goal is development of a manned airbreathing horizontal takeoff and landing space launcher, focused on a single design in October, to be developed by the four-company consortium formed on 24 May from former competitive airframe companies General Dynamics, Rockwell International, and McDonnell Douglas and engine companies Rocketdyne (a division of Rockwell) and Pratt & Whitney. A decision to proceed with construction of an experimental vehicle (designated X-30) is still scheduled for 1993, with the flight-test program possibly starting in 1995 or 1996.

The U.S. also funded conceptual studies of dedicated single-stage-to-orbit vehicle designs, aimed at evaluating the relative merits of horizontal takeoff, airbreathing vehicles vs. winged vertical takeoff (rocket-powered), horizontal landing designs vs. all-rocket vertical takeoff/vertical landing concepts.

Germany has discussed participation in the Saenger program, to develop a reusable two-stage horizontal takeoff space launcher, with other prospective partners (including the Soviet Union), while continuing its US$ 130 million, five-year design definition study. A flight demonstration of the 23-meter Mach 5 first stage prototype could occur by the year 2000.

In France, SNECMA announced in January the creation of a new subsidiary, Hyperspace, to explore propulsion technologies applicable to spaceplanes such as the U.S. National Aerospace Plane, the German Saenger, and the British HOTOL. These differ from Hermes in that they use airbreathing engines rather than rocket launchers. Dassault has proposed a two-stage aerospace plane, Star-H, very similar to Germany's Saenger, as a possible replacement for Ariane 5. France's Ministry of Research and Technology also sponsored a US$ 2.4 million study by two companies and three government organizations to explore the prospects and feasibility of hypersonic airbreathing space launchers.

ESA and Japan signed an agreement to share information on space plane design, along with other areas of space cooperation such as remote sensing and microgravity experiments on the European Retrievable Carrier (Eureca). ESA, meanwhile, is considering the formation of a dedicated Hermes development entity, Euro-Hermes, to improve the efficiency of the development process.

The Soviet Union's Ministry of Aviation Industry and British Aerospace of the UK agreed to explore jointly the use of the Soviet Mrija An-225 cargo aircraft to launch a modified rocket-powered interim version of HOTOL, much as Orbital Sciences in the US uses a B-52 jet to launch its Pegasus rocket. Eventually the interim HOTOL would be replaced by one with an airbreathing engine. Successful ground testing of a full-scale turboramjet was conducted in the Soviet Union, as were extensive analysis and testing of scramjets for single-stage-to orbit propulsion. The "Bor" flight-test complex was developed for aerodynamic and propulsion research at altitudes up to 200 km and flight speeds to 7500 m/s.

C. Other Transportation Services

Progress on the Cape York Space Agency's development of a new space launch site in northern Australia was marked by U.S. government approval of a policy which would allow a U.S. company, the United States Boosters division of United Technologies, to manage the spaceport, which plans to use Soviet Zenit vehicles as

its primary launcher.

Norway undertook a major expansion of its Andoya Rocket Range to meet the growing demand for suborbital launches and, eventually, launches of small satellites (see below). Over 90 launches were made from the range in 1990.

III. UNMANNED EARTH ORBITAL ACTIVITIES

A. Telecommunications

(1) General-Purpose Systems

(a) European Commercial Spacecraft

Arianespace announced in March that it will launch Telecom 2B in late 1991. The spacecraft is being built by Matra Espace and Alcatel Espace for French domestic and military use. It will complement the services provided by Telecom 2A.

The first of a series of 6 Eutelsat 2 satellites was launched in August aboard Ariane. 52 of the series' 96 transponders have already been booked, most for television and radio broadcast services. The design of Eutelsat 2 builds on the experience gained in the first-generation Eutelsat 1. Two transponder bandwidths are available, 80 MHz and 40 MHz (for television and specialized services). Shaped beams were also introduced to allow for different traffic distributions over the continent. The Eutelsat 2 spacecraft are built by a European consortium led by Aerospatiale. Future Eutelsat capabilities will include direct broadcast and mobile services.

Marcopolo 2, orbited by a Delta II launcher on 17 August, will also serve the direct-broadcast market for British Satellite Broadcasting, which sold 54,000 45-cm ground antennas between April and August, with 440,000 expected by the end of 1990.

Spain's Hispasat contracted in January with Matra Espace to build three direct-broadcast satellites and in February with Arianespace to launch two of them in 1992 (one is a spare). The satellites will each weigh 2,075 kg.

Satellites and ground equipment for the Turksat system were contracted to a European consortium led by France's Aerospatiale. Each of the two satellites will carry 16 Ku-band transponders for communications, television broadcasting, video links, and mobile communications. The system is to be implemented in 1993.

Eastern-Europe participation in western satellite communications networks continued to grow, with Poland, Hungary, and Romania joining the European Telecommunications Satellite Organization (Eutelsat) and the USSR expressing an interest in applying for membership in Intelsat and, possibly, merging

Intersputnik with Intelsat. Bulgaria and Czechoslovakia have indicated interest in joining Eutelsat as well. To accommodate the expected traffic increase, Eutelsat plans a new generation of satellites, Eutelsat 3, with 60% more capacity and 250% more power than the current generation.

France's Aerospatiale and Italy's Selenia Spazio signed an agreement on 7 May to cooperate on satellite construction. This agreement, following the earlier merger (in January) of Germany's Dornier and MBB into Daimler-led Deutsche Aerospace, indicates the growing tendency of European space industry to consolidate. Other mergers enacted in 1990 include GEC-Marconi of the UK with France's Matra Espace to form Matra Marconi Space, and Aeritalia Societa Aerospaziale Italiana with Selenia Spazio of Italy.

(b) European Experimental Programs

A newly funded ESA program includes the experimental ARTEMIS satellite and a data relay satellite system. ARTEMIS will carry three advanced payloads to evaluate optical interorbit links, multibeam broadcast, and S-band multiple access. Being built by a consortium led by Selenia Spazio, it is to be launched in 1994.

(c) Asia

The Japanese direct-broadcast satellite BS-2X, lost when its Ariane 44L launcher failed on 22 February (see above), will not be replaced, but will be superseded by the first of a new generation of broadcast satellites, BS-3H, to be launched by a U.S. General Dynamics Atlas rocket in April 1991.

Japan launched another television broadcast satellite, BS-3a, on 28 August, using its own H-1 launcher. The 550-kg spacecraft replaces the first BS-2, launched in 1984. Besides its three broadcast transponders, it carries a special transponder for high-definition television experiments.

The Indonesian communications satellite Palapa B-2R was launched 13 April by a U.S. McDonnell-Douglas Delta II rocket, supplementing two previous Palapa spacecraft launched in 1983 and 1987. Palapa B-2R, which was originally launched by the U.S. Shuttle in February 1984 but failed to achieve its proper orbit and was later recovered, will serve Indonesia, the Philippines, Thailand, Malaysia, Singapore, and New Guinea.

Asiasat, launched by a Chinese Long March 3 rocket on 7 April, was also originally placed in an improper orbit in 1984 as Westar 6, retrieved on a subsequent Shuttle flight, and refurbished. The 1250-kg spacecraft is Asia's first privately funded regional satellite, serving organizations in Hong Kong, Burma, Mongolia, South Korea, Nepal, Bangladesh, Pakistan, and

Thailand. Asiasat plans a second satellite for 1994.

China announced a five-year plan which includes development and launch of a high-capacity communications satellite, Donfanghong 3, which will cover the entire nation with 6 color television channels and 15,000 voice, telex, fax, and data circuits. Two new meteorological satellites are included in the 5-year plan.

In May South Korea revealed a 10-year plan to build and launch remote-sensing and communications satellites and begin developing its own launch system. The first project, which would enlist help from a foreign partner, is a 1993 launch of a 250-kg satellite to survey fishing and agricultural resources. Its launch will be preceded by a small 50-kg test satellite, Korsat, which may be launched as an auxiliary Ariane payload.

India's Insat 1D, a communications and meteorological satellite built by Ford Aerospace, was launched successfully on 12 June aboard a U.S. Delta 4925 rocket. It provides over 4,000 two-way voice and telecommunications circuits, meteorological imaging, and support for over 500 television and radio stations in India. Insat 2A, being built by the Indian Space Research Organization, is scheduled for a late 1991 launch by Arianespace.

(d) United States

On 14 May two Atlanta, Georgia hospitals initiated the use of telecommunications to conduct medical experiments and diagnoses. Developed by Corabi International Telemetrics, the high-resolution satellite-transmitted imaging system will be extended not only to other hospitals but also to the Shuttle and Freedom in orbit.

On 18 May Satellite CD Radio filed a request with the U.S. Federal Communications Commission (FCC) to launch two radio broadcast satellites aimed at nationwide broadcasting to individual residences and automobiles. The company plans their first launch in 1994. Other new FCC applications include Orbital Sciences Corporation's ORBCOMM proposal, a low-Earth orbit messaging-system proposal, Starsys's proposal for a similar system using different technology, and Afrisat's proposal for direct audio broadcast services in Africa (see below).

(e) Soviet Union

The Energiya Scientific Production Association announced plans for a three-satellite system using the largest communications satellites conceived to date. Each 18-tonne satellite is planned to carry 8 television channels, 16 stereo radio channels, and sufficient capacity for 150 million telephones. Trial launches of smaller test satellites are expected in 1991 or 1992, with the first operational satellite

launch expected no earlier than 1993.

(f) Other Regions

Brazil contracted in April with Hughes (U.S.) and Arianespace (Europe) to build and launch two new communications satellites in 1994. Brazil's communications agency Telebras expects the country's two current satellites to last until 1993 and 1994 respectively.

(g) International

The failure on 14 March of a commercial Titan 3 rocket to deliver an Intelsat 6 to its proper orbit left the spacecraft in a useless and perilous low elliptical orbit. Circularized by expenditure of some of its onboard propellant, the orbit was stabilized and the spacecraft (self-insured by Intelsat) now awaits a Shuttle rescue mission in late 1991 or 1992 to install a new transfer stage able to boost it to its operational geostationary orbit. A second Intelsat 6 was successfully launched by a Titan 3 on 23 June. It has been stationed over the Atlantic, where its capacity for 120,000 simultaneous telephone calls and three television channels will meet the demand originally intended to be satisfied by the stranded spacecraft.

Alpha Lyracom began data services via PanAmSat 1 in Costa Rica, Chile, Peru, the Dominican Republic, Haiti, Ecuador, Colombia, and Sweden, with service to begin soon in Panama, Jamaica, Trinidad, and Guatemala. Costa Rica and Dominica are building new teleports for this and other satellite communications services. Mexico announced plans to build two new satellites, the first of which, called Solidaridas, would be launched in 1992. The new satellites will supplement the two Morelos spacecraft launched in 1985. Telecommunicaciones de Mexico (Telecomm) also signed an agreement with the U.S. firm GTE Spacenet on 18 June to provide communications services in the U.S. and Mexico using very small aperture terminals (VSATs).

A new venture, Afrispace, was proposed on 23 July to provide digital radio broadcasts to Africa and Arabia from a small, 800-kg satellite to be launched in 1993. The company plans to award a contract for 100,000 radio receivers early in 1991.

(2) Mobile Systems

Mobile satellite service activity burgeoned this year, with both ground-mobile and aeronautical services introduced by Inmarsat, initiation of transmissions by Canada's Telesat Mobile, Inc., and entry of Eutelsat's Euteltracs system for both mobile communications and position location. Fifty commercial aircraft were fitted with antennas to inaugurate Inmarsat's aeronautical communications system this year. Another aeronautical

communication service using Inmarsat satellites, Skyphone (a consortium of British Telecom, Norwegian Telecom, and Singapore Telecom), completed testing its UK ground station and initiated commercial services this year. Additional ground stations, in Norway and Singapore, were also completed. Two other aeronautical communications consortia were formed this year: Comsat (U.S.) with Kokusai Denshin Denwa (Japan), and Societe Internationale de Telecommunications Aeronautiques (France) with France Telecom, OTC Ltd. (Australia), and Teleglobe Canada. Both will begin services next year.

Inmarsat contracted with GE Astro Space in the U.S. to build three or four Inmarsat 3 next-generation mobile communications satellites, plus options for five more. The first of four Inmarsat 2 satellites were delivered this year, and was launched aboard the 200th Delta vehicle on 30 October. It will increase capacity over the Indian ocean sixfold.

The U.S. Federal Communication Commission endorsed the use of L-band frequencies for mobile satellite communications use, although its 9 February decision still must coordinate the use of these bands with Inmarsat and with other countries planning mobile satellite systems.

In June Motorola of the U.S. announced plans to develop and launch a constellation of 77 small satellites for digital global mobile telephone and radio service. The satellites will weigh about 315 kg and be placed in 7 polar orbits each containing 11 satellites. The first launches will occur in 1994.

Australia will begin mobile service with Aussat B, whose two satellites are scheduled for launch on Chinese Long March rockets in 1991 and 1992.

Telesat Mobile of Canada and American Mobile Satellite Corporation of the U.S. signed a joint agreement on 25 April to provide compatible mobile satellite services throughout the U.S. and Canada, including backing each other up. Two separate contracts are expected, one by TMC and one by AMSC, for two nearly identical Hughes spacecraft based on the HS-601. The first satellite in this integrated North American system will fly in 1993.

Japan announced plans for a satellite to test technologies for quick relaying of communications among mobile satellites. The ETS-6 test satellite, to be launched in 1993, will evaluate optical lasers and S-band transmissions.

NASA also announced its Advanced Communications Technology Satellite (ACTS) Mobile Terminal Program to develop very small Ka-band transceivers for use with ACTS, scheduled for launch in May 1992.

(3) Navigation and Position Location

The French firm Locstar, with 42 institutional shareholders, ordered two 1500-kg satellites from Matra Espace, to be launched by Arianespace in 1992. The European market for position-location terminals in this decade is projected at one million. The U.S. company Rockwell International launched a truck-location service (using American Mobile Satellite Corp. spacecraft) in competition with Geostar, Inc.

On 9 May the U.S. Global Positioning System (GPS) was declared to be operational, with 13 of the projected full complement of 21 satellites and 3 spares that are expected to be in orbit by 1993. The system is designed for use by both U.S. military forces and civil organizations worldwide.

On 30 May U.S. companies Northwest Airlines and Honeywell signed an agreement with the Soviet Ministry Aviation Industry to assess the integration of GPS with the Soviet Global Orbiting Navigation Satellite System (GLONASS). The first flight tests of the integrated system are scheduled by Northwest Airlines for December 1991.

Japan's Mazda Motor Corporation will offer this year a satellite navigation option on its domestic model Eunos Cosmo automobiles. The navigational system, developed jointly with Mitsubishi Electric, uses Global Positioning System receivers in conjunction with digitized maps to provide location accuracy of about 30 meters.

B. Earth Observations

France's SPOT-2 was launched on 21 January by the first Ariane 4-0 rocket (which has no booster rockets), joining SPOT-1 in an 800-km orbit. SPOT-3 is scheduled for launch in 1993, and SPOT-4 in 1996. The SPOT system operator, Spot Image, turned its first profit in 1989, on revenues of US$ 22.2 million.

ESA approved initiation of the ERS-2 Earth observation satellite on 27 June. It will be launched in 1994, following next year's launch of its predecessor, ERS-1.

On 3 September China launched its second weather satellite, Feng Yun 2, on a Long March 4 rocket. The spacecraft will generate domestic and foreign weather data for forecasting, and conduct research studies of the ocean and the atmosphere.

The U.S. National Oceanic and Atmospheric Administration (NOAA) received approval to proceed with development and launch of Landsat 6, which will succeed the present Landsat 4 and 5 spacecraft.

The U.S. approved initiation of the Earth Observing System, the main element in Mission to Planet Earth, a 15-20 year program to obtain and analyze the data needed to construct reliable,

accurate predictive models of the Earth's biosphere for use in long-term environmental planning. EOS will include four large polar-orbit platforms (plus replacements), two built by the U.S., one by Europe, and one by Japan, as well as a number of smaller Earth Probes and a massive ground-based data reduction and processing capability. The first large U.S. platform, to be launched into its polar orbit by a Titan 4 in 1997, will cost over US$ 800 million and weigh about 13,500 kg.

Definition studies for the EOS Data and Information system (EOSDIS) were conducted this year, indicating that EOSDIS will be able to cope with the enormous data flow expected from the system. Seven EOS data archive centers have been established in the U.S., and contracts for EOSDIS are expected to be issued in 1992.

The Soviet Union launched Almaz to conduct commercial radar observations. The 18.5-tonne spacecraft, based on the military Cosmos 1870, is able to store digital images on magnetic tape and transmit them back to Earth. Almaz's resolution is estimated at 15 meters.

The Soviet Space Research Institute announced in October a new series of polar-orbiting platforms called Ecos, to collect data on atmospheric chemistry, radiation fields, and effects of pollution. The first Ecos platform is planned for launch in 1996. Meanwhile, a pressurized environmental data collection module Priroda (Nature) will be launched to Mir in 1992, and a new generation of Soviet meteorological satellites will be launched from 1993 to 1995.

The first East-West joint space venture to follow the unification of Germany, announced on 4 October, will team Munich's MAN Technologie and Jena's Carl Zeiss GmbH for remote sensing applications and also space testing services via a new joint company, Optosys.

C. Small Satellites

1990 saw a major expansion in activity centered on the use of small satellites for both communications and remote sensing applications. One of the more interesting proposals, by Edward Teller of the U.S., was for a system of "Brilliant Eyes" (copying the terminology defined by the U.S. strategic defense concept called "Brilliant Pebbles"), in which thousands of two-to-four kg sensors would be orbited to gather the massive amounts of environmental data needed to create the predictive models which are the goal of the International Geosphere/Biosphere Program, currently planned to be accomplished by the Earth Observing System (see above). The tiny satellites could also warn affected populations about typhoons, tsunamis, cyclones and other storms, dam failures, nuclear powerplant accidents, and other catastrophes. The technology for "Brilliant Eyes" is not yet available, but could be a byproduct of ongoing "Brilliant

Pebbles" and similar miniaturization programs. The U.S. National Research Council, however, has rejected the idea that "Brilliant Eyes" might be used for the Earth Observing System (EOS).

The U.S. National Oceanic and Atmospheric Administration (NOAA) is considering the use of small satellites to replace its traditional large meteorological spacecraft. NOAA is evaluating lightsats for radiation-exchange measurements, ozone mapping, and search and rescue.

On 18 April the U.S. Air Force contracted with TRW and Defense Systems Inc. to build up to 12 "lightsats," the first of which is to weigh less than 400 kg and carry four scientific experiments to an elliptical polar orbit with an apogee of 1500 km and a perigee of 195 km. Two of the four experiments will study upper atmospheric effects on radio; one will measure the density of electric fields; and one will measure the drag on the satellite. The payload will be launched on a Pegasus vehicle in 1992.

On 9 May the U.S. Defense Advanced Research Projects Agency (DARPA) launched two Multiple Access Communications Satellites, each weighing 70 kg, into slightly elliptical low polar orbits using a single Scout launch vehicle. These satellites were later used to support logistics requirements for international forces in Saudi Arabia.

NASA approved a program to develop and launch small recoverable satellites for month-long commercial experiments. Payloads for the Commercial Experiment Transporter (COMET) could weigh up to 800 kg.

IV. MANNED EARTH ORBITAL ACTIVITIES

A. Space Stations

(1) The Soviet Mir

On 1 and 5 February Cosmonauts Alexander Serebrov and Alexander Viktorenko flight-tested a "space motorcycle" at the Mir space station. The five-hour test on 1 February took Serebrov up to 30 meters from the Mir; the four-hour flight on 5 February carried Viktorenko 200 meters away and included a full 360-degree roll. The SPK vehicle, which is similar in appearance and function to the Manned Maneuvering Unit used by U.S. Shuttle astronauts, weighs 200 kg and has a maximum flight duration of 6 hours.

On 31 May the Kristall module was launched to Mir, and subsequently docked with the station on 10 June. The 19.5-tonne laboratory is equipped with six furnaces to produce semiconductor alloys and materials, four electrophoresis chambers for the manufacture of pharmaceuticals, and a number of optical

instruments including an ultraviolet telescope. Besides Kristall, Mir now consists of the original 20.4-tonne core, the 11-tonne Kvant-1 astrophysics module, and the 19.6-tonne Kvant-2 logistics module, along with the current Soyuz crew transport vehicle and Progress supply vehicle. The Soviet Union also announced plans to use the Buran space shuttle to demonstrate a cosmonaut rescue in 1991 by docking with the Mir station and a Soyuz spacecraft.

In July cosmonauts Alexander Balandin and Anatoly Solovyov went outside Mir for an unprecedented seven hours to repair insulation panels on the Soyuz TM-9 return vehicle. They had to go out again later in the month to attempt (unsuccessfully) to repair Mir's airlock, which had failed to close properly, and to retrieve ladders and other tools they had left behind when their first EVA had approached their suits' limits.

Discussions aimed at Soviet-U.S. cooperation between the Soviet Mir and the U.S. Shuttle were initiated, with tentative agreement reached for a U.S. astronaut to fly on Mir and a Soviet cosmonaut to fly on the Shuttle. 1992 would be the earliest possible date for the exchange.

Two Japanese reporters completed their training for a flight in Mir. The flight, for one of the two, is scheduled for the end of this year. China has also opened discussions with the Soviet Union to fly a Chinese astronaut aboard Mir in mid-1993.

(2) Space Station Freedom

Preliminary Design Review (PDR) of Space Station Freedom was begun in May and is scheduled to be completed by the end of the year. Three major problems encountered in the early design stages were excessive extravehicular activity needed for maintenance, too high an electric power demand for "housekeeping" services, and over-design mass. These problems either have been solved or their solutions appear to be in reach by completion of the PDR, although one additional Shuttle flight may be needed to deploy the station. Cutbacks during the annual budget appropriations by the U.S. Congress, as well as concerns about excessive reliance on the U.S. Shuttle for deploying and servicing the station, continue to pose major schedule, capability, and cost concerns.

ESA changed the design of the free-flying Columbus laboratory's Resource Module to replace it every five years instead of being serviced extensively in space. The free-flyer is scheduled to be launched to Freedom in 1998 aboard an Ariane 5 rocket. There were no design changes this year in the Columbus Attached Laboratory or the Polar Platform.

Canada's contribution to Freedom is the Mobile Servicing System, which consists of three main elements:

(a) The Mobile Service Center, whose large grappling

arm will help assemble the station, dock the Shuttle to the station, and load and unload the Shuttle's cargo bay. Design review was completed in 1989, and construction began this year.

(b) The Special-Purpose Dextrous Manipulator, which will perform many delicate servicing tasks such as cleaning, replacing components, and repairing fuel lines and electric circuits. A preliminary design review was conducted at the end of this year.

(c) The Maintenance Depot, which will maintain Canadian systems and possibly service other hardware. It is scheduled for preliminary design review early next year.

Japan selected eight contractors for Freedom's Japanese Experiment Module (JEM) this year. The JEM has three elements: a pressurized module, a facility exposed to space, and a logistics module.

B. The Space Shuttle

U.S. Space Shuttle Columbia retrieved the Long Duration Exposure Facility (LDEF) on 19 January after nearly six years in orbit. Its 57 experiments, designed to see how different materials withstand long exposure to atomic oxygen, radiation, micrometeoroid dust, and debris (see below), will be useful in designing future space stations.

C. Other Manned Orbital Programs

Japan's NASDA initiated studies by five companies to explore a Japanese Manned Platform to be orbited by five launches of the H-2 rocket. It would support up to three crew members on 3-month shifts, and would be used primarily for microgravity experiments.

ESA, too, has begun to plan for its own space station, to be serviced by Hermes and support a crew of three on four-to-six month shifts. It would be crew-tended by 2003 and permanently manned by 2006.

D. Life Sciences Research

The U.S. Lifesat program to collect data on the long-term effects of space radiation -- one of the most critical needs in designing long-term human space exploration missions -- may be curtailed due to budget growth. Two designs have been proposed for the recoverable Lifesat capsule, one based on the Discovery research capsule which has flown over 400 times, and one based on using a tether between two spacecraft modules to allow varying degrees of artificial gravity to be tested. The first launch is currently scheduled for 1995.

A month-long test to explore the psychology of group interactions over long periods was conducted by ESA at the Norwegian Underwater Technology Center in Bergen, Norway. Six men with technical backgrounds remained isolated from 17 September to 15 October.

V. SPACE EXPLORATION

A. Unmanned Systems

The Cosmic Background Explorer (COBE), launched by the U.S. in November 1989, reported a wholly unexpected uniformity in the microwave radiation that emanated from the early formation of the Universe, instead of the uneven bursts that one would predict from the existence of complex structures such as galaxies. The spacecraft was the first to image the interstellar dust in the entire Milky Way galaxy. COBE ended its useful life on 21 September, when the liquid helium used to cool its sensors was consumed.

NASA's Voyager 1 spacecraft, which explored Jupiter and Saturn after its 1972 launch, photographed 64 images of seven planets (Pluto and Mercury were not visible) from its 13 February location 6 billion km from Earth. This was the first (and, for the foreseeable future the only) opportunity to view the entire Solar System from an exterior vantage point.

The major space-science event of the year was the launch of the U.S.-ESA Hubble Telescope into its 600-km orbit on 24 April by U.S. Space Shuttle Discovery. Initial problems with antenna deployment, unexpectedly large effects on software by Earth magnetic-field anomalies in the telescope's orbit, and dynamic oscillations of the solar panels due to thermal shock upon entering and leaving Earth's shadow were solved, but it was later found that the 2.4-m primary mirror had been ground improperly so that it suffered from spherical aberration. Fortunately, however, the exact cause of the error was identified (it was a measuring device used to guide the grinding process), so that the replacement wide-field and planetary camera originally scheduled to be installed by Shuttle astronauts in 1993 can be fitted with six 2-cm diameter "eyeglasses" that are expected to correct fully the mirror's aberration. Meanwhile, ultraviolet and spectrographic observations can proceed unimpeded by the mirror's aberration, and computer enhancement of the uncorrected wide-field camera's images have proven surprisingly effective in helping to generate data of far higher quality than can be obtained with Earth-based telescopes.

One of the Hubble's five primary instruments, the faint-object camera, was developed and built by ESA. Although the primary mirror aberration will seriously compromise the results anticipated from this camera, ESA does not have the budgeted

funds available to replace it with corrective lenses as is being done with the wide field camera. However, the ESA camera is imaging stars with far better resolution than can be obtained with Earth-based telescopes, and has already generated extremely exciting data, including the best picture ever taken of Pluto and its moon Charon. The ESA camera was also able to resolve over 200 individual stars in the globular cluster M14, where ground-based telescopes had seen only 15.

The U.S. Jet Propulsion Laboratory issued a request for proposals on 11 June for the fourth Great Observatory, the Space Infrared Telescope Facility (SIRTF). Construction is scheduled to start in 1993, with launch in 1999. Of the other three, the Hubble Telescope is in orbit, the Gamma-Ray Observatory will be launched next year, and the Advanced X-Ray Astrophysical Observatory is being built for launch in mid-decade.

After solving software problems believed to be caused by the rocket motor which inserted the Magellan radar mapper into its polar orbit around Venus, the spacecraft in September began its year-long mission of mapping most of the Venusian surface. The first radar images were excellent, revealing surface characteristics of the cloud-shrouded planet that have caused great excitement among planetary scientists. Among the areas to be surveyed are the sites where Soviet Veneras landed early in the 1980s.

On 6 October the long-awaited launch of ESA's Ulysses spacecraft finally took place. The launch, by U.S. Shuttle Discovery, was followed by acceleration of the 370-kg spacecraft using three solid-propellant stages (a two-stage Inertial Upper Stage and a single-stage Payload Assist Module) to the highest spacecraft velocity ever achieved. After a gravity-assist at Jupiter in February 1992, to fling Ulysses out of the ecliptic plane, the spacecraft will survey for the first time both polar regions of the Sun, beginning in May 1994.

Japan became the third nation to send a spacecraft to explore the Moon when it launched 200-kg Muses-A on 24 January, using an M-3S-2 solid-propellant 3-stage rocket. Muses-A, renamed HITEN after launch, followed an elliptical Earth orbit which came within 10,000 miles of the Moon, where it launched a sub-payload into lunar orbit. Unfortunately, communications with the lunar orbiter were lost after 50 days. The last spacecraft sent to the Moon was the Soviet Luna 24, in 1976.

A U.S. General Dynamics Atlas 2AS rocket was selected in March to launch the ESA/NASA Solar and Heliospheric Observatory (SOHO), scheduled for 1995. ESA is designing and building the spacecraft, which will study the Sun's interior and the origins of the solar corona and solar wind.

ESA's geostationary-orbit Hipparcos satellite, which was left in a highly elliptical orbit last year due to a component failure in its apogee rocket, has nevertheless proved highly

successful in its mission of cataloging the distances between stars. However, its plunges through the Van Allen radiation belts on every orbit have degraded its sensors and its solar panels so that it cannot see the fainter stars, and therefore will not be able to catalog all 120,000 stars it was originally intended to measure. ESA decided in May not to launch a replacement, but instead to use a fourth ground station (at NASA's Goldstone facility in California) to try to complete Hipparcos' mission before radiation damage ends the spacecraft's useful life.

On 1 June a Delta II rocket launched the German-U.S. Roentgen Satellite (Rosat) into a 600-km orbit. Rosat's X-ray instruments will perform a 6-month all-sky survey and then study 1450 astronomical targets, including quasars, black holes, binary stars, and exploded stars. Calibration exercises in June and July produced excellent X-ray images of a galaxy cluster (Abell 2256), a neutron star (Cygnus X-2), and a supernova remnant (Cas A).

ESA's Halley comet explorer Giotto, reawakened after a four-year dormancy, became the first deep-space mission to return to Earth's neighborhood, flying by our planet in July 1990.

A contract for production of the Infrared Space Observatory was signed on 17 September. Aerospatiale of France will build the ESA satellite, to be launched in 1993 by Arianespace.

ESA and the Soviet Union signed a broad space cooperation agreement on 25 April covering space exploration, space astronomy and astrophysics, Earth observation, meteorology, life sciences, microgravity research, and other fields. The Soviet Union also signed an agreement with China pledging cooperation on mutually beneficial peaceful uses of space.

The USSR renewed its commitment to the Mars 94 mission, despite cutbacks in the overall Soviet space budget that necessitated some reduction in capability of the two Mars orbiters. Mars 94 is part of the Soviet Science Academy's Mars Exploration Program. Two launches are scheduled for 1994, each with a Phobos-type orbiter bus and a descent module. The descent module will include a French balloon, whose guiderope is being developed jointly with the U.S. Planetary Society, and a small Soviet-developed rover. The balloon gondola and all ground stations will communicate via a French relay with both the Mars 94 orbiters and the U.S. Mars Observer spacecraft currently scheduled for launch in 1992. Germany is providing the high-resolution stereo television system for the Mars 94 orbiters, and France the television equipment for the balloon gondola and a data compression unit.

The Soviet Union also laid out an ambitious plan for robotic space missions over the next decade which will use instruments aboard Mir as well as Earth-orbiting satellites to monitor the entire electromagnetic spectrum from radio frequencies to gamma rays. The program will use the 20-tonne Priroda scientific module due to be launched to Mir in 1991, the robot Spektr-Rentgen-Gamma

observatory to be launched in 1993, and a linked ground-based network of radiotelescopes providing an effective antenna diameter of thousands of kilometers.

In May designs were released for the six national entries for the Columbus 500 Space Sail Cup, to be launched to Mars during the International Space Year in 1992. The Soviet Union has offered to launch them for US$ 25 million. The entries are from Canada, China, Italy, the Soviet Union, The U.K., and the U.S.

B. Manned Systems

The U.S. conducted an extensive "outreach" program to solicit and assess new, innovative approaches and technologies applicable to the Space Exploration Initiative (SEI) announced by President Bush last year, whose goal is to reestablish a permanent human presence on the Moon and begin the manned exploration of Mars. The program is designed to define several alternative mission architectures early in 1991 and to identify high-payoff technologies that might reduce program risk, cost, and time or enable more to be accomplished. Although the U.S. Congress deleted budgetary support for the SEI for the coming year, low-level studies by both NASA and several aerospace companies are expected to continue, along with discussions of possible cooperation with other nations, particularly Europe, Japan, Canada, and the Soviet Union.

Japan's NASDA initiated studies of a manned lunar base. They would last two to three years and be conducted by the same eight companies currently working on the Japanese elements of Space Station Freedom.

VI. TECHNOLOGY ADVANCEMENT

A. Propulsion

U.S. activities in rocket propulsion are aimed primarily at reducing engine costs and improving safety, reliability, and operating lifetime. Pratt & Whitney completed testing of its new RL-10 A-4 engine, whose new liquid oxygen pump and extendable nozzle have increased its thrust by 25%, to 11,400 kg. The Shuttle's Advanced Solid Rocket Motor development is proceeding on schedule, but alternatives are still under investigation; e.g., improving the current Thiokol Redesigned Solid Rocket Motors or designing new liquid-rocket boosters, which offer engine-out capability.

On the National Aerospace Plane program, several integrated subscale supersonic-combustion ramjets (scramjets) have been tested up to Mach 8.

In non-chemical propulsion, GE Astro Space has selected a 1.8-kW hydrazine arcjet for north-south stationkeeping on the

AT&T Telstar 4 satellite. The U.S. Air Force announced in April a requirement for solar-electric upper stages to replace some chemical rockets currently used for orbit transfer by the year 2000. The new stages would use photovoltaic arrays to transfer payloads weighing 7,000 kg from low Earth orbit to the geostationary orbit.

Both nuclear thermal rockets and nuclear-electric propulsion have resurfaced as major prospects for reducing either trip time or required mass in low Earth orbit for missions to Mars being contemplated for the Space Exploration Initiative (see above). Assurance of safety is seen as a major concern in pursuing these developments. Very high acceleration launch technologies such as electromagnetic coilguns and light gas guns are being considered for orbiting large quantities of small acceleration-insensitive payloads, as is laser propulsion in several configurations.

European propulsion emphasis has been on development of the Ariane 5, whose first launch is scheduled for 1995. Five tests were completed this year by SEP on the first full-scale Vulcan oxygen-hydrogen test engine for Ariane 5, and a second test engine has been built for other tests by MBB. The P230 solid-propellant booster was first tested subscale in 1989; a full-scale test is scheduled for 1991. The 27.5-kg thrust storable-propellant upper-stage engine was successfully tested without a nozzle.

MBB tested a liquid-hydrogen-fueled ramjet engine of the type that would be used in Saenger's first stage, demonstrating over 1 tonne thrust for 25 seconds at Mach 4. Europe is also developing small electric thrusters for satellite orbit transfer and attitude control, with xenon ion engines developed by Germany and the UK slated for flights on Eureca in 1991 and SAT-2 in 1993.

The Soviet Union has offered for sale the RD-170 engine that powers the Zenit and Energiya launch vehicles. The oxygen-kerosene engine, which is currently the world's largest liquid-propellant rocket engine with 806 tonnes thrust, has been fired 650 times, the last 400 without failure.

Japan's propulsion activities center on the H-2 engines. The first-stage LE-7 has encountered development problems necessitating reducing its thrust by about 8%. The second-stage LE-5, an improved version of the H-1's engine, has been successfully tested, as have the solid-propellant boosters. Development of a larger version of the M-5 solid-propellant launcher used by the Institute of Space and Astronautical Science has been approved for launch in 1994. Japan plans to equip its ETS-6 engineering test satellite, to be flown in 1992, with a xenon ion propulsion thruster for north-south stationkeeping and its Space Flyer Unit, scheduled for 1994, with a hydrazine magnetoplasmadynamic engine.

Japan's aerospace plane effort, led by the National

Aerospace Laboratory (NAL), included running supersonic wind-tunnel tests on a a scramjet inlet model and ramjet combustor tests on an air turboramjet concept. NAL plans to build a scramjet test facility. Recent design and test emphasis has been on a liquid air cycle engine.

India's work in propulsion has focused on attitude and orbit control and the apogee motor for Insat 2, which use monomethyl hyrazine and nitrogen tetroxide propellants; the second and fourth stages of the Polar Satellite Launch Vehicle (PSLV); and a thrust vector control system, using aqueous strontium perchlorate, which has been successfully tested with the 125-tonne PSLV solid-propellant booster. India has also completed successful testing of a water-cooled subscale version of the indigenous cryogenic rocket motor slated to be used for its Geosynchronous Launch Vehicle.

B. Power

The U.S. Air Force and NASA have reactivated research on thermionic fuel elements (TFE) for nuclear reactor space power systems of the type flown by the Soviet Union in the Topaz reactor that powers their Radar Ocean Reconnaissance Satellites (RORSATS). Such research was conducted actively in the U.S. about two decades ago. The Soviet Union suggested that U.S. and Soviet TFEs could be tested together in a joint test facility. Space applications might include a global air traffic control radar satellite system, lunar-base power, and electric propulsion for an international Mars mission.

The Soviets have demonstrated single-cell thermionic fuel elements with 5-year lifetimes for the advanced Topaz reactors, which weigh 980 kg and produce 5 kWe. Results of Soviet research and development in this area include high-strength, high-temperature single-crystal refractory metal alloys; high-strength polycrystalline tungsten and molybdenum alloys in ingot or wire form; a resistively heated high-temperature heat source for ground-testing TFEs; oxidation-resistant coatings for niobium and its alloys that permit multi-year use at up to 1100 K; single-crystal hexagonal tungsten for TFE elements; a magnetically pumped cesium dispenser for TFEs; capability for welding molybdenum, niobium, and tantalum to stainless steel; single-crystal sapphire insulators for TFEs; plasmadynamic thrusters; and W-184 enriched tungsten (90-96%).

The U.S. has developed production capability at Applied Solar Energy Corporation for gallium arsenide solar cells on a germanium substrate, and has produced such cells in sizes up to 6 cm square and in thicknesses down to 0.2 mm. Martin Marietta has been awarded a contract to develop solar arrays able to survive massive radiation doses over a wide range of the electromagnetic spectrum.

Japan announced the first use in space of indium phosphide

photovoltaic cells in the lunar orbiter, a subsatellite of the HITEN launched on 24 January. The thousand-cell body-mounted array produces 10-15 watts at an efficiency of 17%.

C. Materials

1990 saw extensive use of advanced composites. The new Pegasus vehicle, for example uses a structure 98% of which was fabricated from various composites.

Spacecraft materials exposed to the space environment for nearly six years on the Long Duration Exposure Facility (LDEF), which was returned to Earth by the U.S. Shuttle on 19 January, included polymeric films and composites, metal-matrix composites, polished metals, glasses, ceramics, solar cells, solid-rocket materials, and thermal control materials. Initial results of the analysis of LDEF's experiments indicate no surprises, with more atomic oxygen and micrometeoroid/debris damage on leading-edge surfaces than elsewhere.

D. Automation, Robotics, and Teleoperators

The U.S. unveiled two preliminary versions of a Mars automated rover concept, one using six articulated legs (developed by Carnegie-Mellon University); the other employing large balloon-like wheels (developed by the Jet Propulsion Laboratory).

E. Space Debris

Space debris was recognized as an even more serious problem this year when the number and distribution of debris objects was reestimated to be considerably greater than the previous (1984) estimate. ESA and Japan have established new requirements to vent all upper stages, which have historically been the largest sources of debris due to explosion of leftover propellant. A number of measures are being considered for use with Space Station Freedom to preclude debris damage. Results of impact experiments lasting six years on the Long-Duration Exposure Facility, however, suggested that the danger to Freedom may be lower than the analytical projections indicate.

In an interesting use of an old satellite, the U.S. was able to reactivate the Space Electric Rocket Test (SERT) 2 satellite, launched in February 1970, to conduct experiments on the long-term effect of impacts by micrometeoroids and small debris particles. The first reactivation took place in 1988 and returned useful data until December 1989. It was reactivated again in June 1990 and will remain illuminated by the Sun until December for a second series of data on degradation of its polished aluminum mirrors.

F. Microgravity Research Facilities

On 28 March, the European consortium Intospace and the U.S. firm Space Industries International (SII) announced a cooperative marketing agreement for SII's Sheet Float Zone Furnace, flown aboard a specially equipped KC-135 aircraft, and for Intospace's Suleika superconductor test package, which flies on Soviet Soyuz spacecraft. The SII furnace, which weighs 225 kg, can melt and resolidify 40 test samples per day during the KC-135's 25-second periods of microgravity flight.

Intospace also signed a 10-year cooperative memorandum of understanding with Japan's Space Utilization Promotion Center. The 9 October agreement calls for mutual logistic support in Germany and Japan.

Japan's three-part microgravity research program began this year with 10-25 second parabolic aircraft flights by the Diamond Air Service. A 500-m drop tower providing 10-second microgravity test periods was completed, and will enter service early in 1991, as will a smaller (100-m) tower. Six-minute microgravity periods will be offered by the TRIA sounding rocket, a quarter-scale version of the H-2, beginning in mid-1991.

A 146-m drop tower built by Germany's Center of Applied Space Technology and Microgravity at the University of Bremen went into service on 28 September. It provides about 5 seconds of microgravity for 150-kg payloads. Over 1200 orders for drops had been received by the end of the year.

The November 1990 Texus 23 sounding-rocket mission, launched from Kiruna, Sweden, demonstrated a new operating mode using telepresence. Fully controlled from the Italian control center at Fucino, this experiment could herald a highly effective method to allow scientists from nations unable to afford extensive space facilities to conduct their experiments from local laboratories.

Aeritalia Space Systems, Italy, received a contract to begin designing Carina, a 500-kg recoverable microgravity experiment capsule slated for launch in 1993 aboard a Scout II rocket from the San Marco launch site in the Indian Ocean.

The U.S. company Spacehab received a NASA contract to develop two pressurized microgravity experiment modules for the Shuttle. Japan and Italy have major interests in the company, which has already booked 82% of mid-deck locker space available on its first six Shuttle missions over the next four years. Europe's Intospace and the Canadian Space Agency are among the customers booked.

The Soviet Union has proposed launching very large free-flying experimental platforms (up to 100 tonnes) for use in microgravity and materials processing experiments. A prototype of this platform was the first Energiya payload, which was launched

on 15 May 1987 but failed to achieve orbit.

The recoverable 500-kg Swedish Mikroba capsule, which can carry a payload of 200 kg, underwent successful drop tests from a balloon at 43 km altitude. The system uses three parachutes in stages to deposit the payload safely on Earth.

G. Microgravity Research

The European Commission of the European Community committed US$ 3 billion (through 1992) to microgravity research within the scope of four existing programs: Basic Research in Industrial Technology for Europe, European Research in Advanced Materials, Biotechnology Research Program for Innovation and Development Growth in Europe, and The Science Program.

France's CNES flew its experimental crystal-growth payload Crocodile aboard a recoverable Soviet Photon capsule, launched by a 3-stage Soyuz, on 11 April. The 17-kg payload grew high-quality organic crystals for optical processing in advanced electronic circuitry.

The U.S. company Payload Systems Inc. recovered their protein crystals, grown in 112 chambers aboard the Soviet Mir space station, on 19 February. The crystals aid the design of new pharmaceutical products. The U.S. Consortium for Materials Development of the University of Alabama at Huntsville launched its third microgravity experiment 17 May on a Starfire 1 sounding rocket. The 400-kg payload carried 12 experiments. The recent burgeoning of this type of suborbital experiment, incidentally, has created a new market growth opportunity for the world's space insurance industry, since the current market in orbiting spacecraft has leveled out.

H. Astrodynamics, Guidance, Navigation, and Control

The high accuracy achieved by current systems was demonstrated by the Magellan mission to Venus, in which only 20% of the spacecraft's propellant was needed for mid-course corrections. Similar performance has characterized the Galileo mission, currently enroute to Jupiter in 1995. The use of Earth for gravity assist maneuvers was demonstrated for the first time this year with the European Giotto spacecraft, providing Giotto with the velocity needed for its encounter with the comet Grigg-Skjellerup in July 1992. Galileo will use the Earth twice for gravity-assist acceleration on its way to Jupiter.

VII. EDUCATION

The International Space Year (ISY) is the focus for a number of educational activities being organized by regional ISY associations formed by ESA, Japan's NASDA, and the U.S. The Space

Agency Forum for the ISY (SAFISY), an organization of 25 space agencies worldwide, has selected Mission to Planet Earth as its major focus, with ten specific projects identified. Proposals for another 40 projects in education, applications, and science are also being considered.

The International Space University (ISU) session in Toronto, Canada, focused on two projects: an international asteroid mission and the international Earth observation program. Previous ISU projects included an international lunar base, a variable-gravity research facility, and a lunar polar orbiter. The 1991 session will be in Moscow, with Japan scheduled for 1992. ISU is seeking a permanent campus to be implemented in 1992.

In the U.S., NASA and the newspaper USA Today created an elementary-school curriculum called "Visions of Exploration: Past, Present, and Future," to contrast current space exploration plans with those of past explorations on Earth. Distribution to the schools will be by satellite.

The Space Telescope Science Institute, with NASA and other U.S. astronomical institutions, inaugurated the Hubble Postdoctoral Fellowship Program, which will fund up to 45 astronomers for three one-year terms.

Hughes Space and Communications Co. in the U.S. announced a program to deliver free educational programming by satellite to school grades from kindergarten through fifth grade, eventually aimed at reaching 6,000 schools. Antennas will be provided by Hughes at no cost.

The National Space Society sponsored a National Youth Education Week and a Mission to Planet Earth Day. Its National High-School Debate Topic, which focuses on the Space Exploration Initiative, will involve more than 100,000 students across the U.S. The National Space Society also created the concept for a Youth Space Education Week, which was endorsed by a U.S. Senate Resolution calling on school systems and other educational organizations to involve students in various hands-on space related activities in celebration of the event. The first annual Youth Space Education Week was celebrated 8-12 October, 1990.

In Japan the Young Astronauts Club has garnered about 4,000 members, and NASDA has invited international graduate-level students to train in its national research institutes.

In France the new merged company Matra-Marconi Space has created a space technology school for entry-level engineers and a computer research laboratory to accommodate students. Other countries report similar developments. The UK's Serco Space Ltd. has developed a classroom curriculum using remote-sensing photography, another trend with wide appeal in many countries.

VIII. SPACE LAW

The United Nations Committee on the Peaceful Uses of Outer Space, after a decade of deliberations and negotiations, is nearing completion of its work on a set of international principles to govern the use of nuclear power sources in outer space. Based on technical criteria for the safe use of nuclear power sources in outer space agreed upon in the Scientific and Technical Sub-Committee, the Legal Sub-Committee was able to expand the agreed draft principles to six, with five draft principles remaining under discussion. The newly agreed draft principle on "guidelines and criteria for safe use" provides, among other criteria, that nuclear power sources should be used only when non-nuclear sources cannot be employed; that nuclear systems should be designed and operated to prevent any significant radioactive exposure of people or contamination of the space environment; that nuclear systems should have safety mechanisms that take account of foreseeable failures or malfunctions, and that when nuclear power sources are used in low Earth orbit, provision should be made for their long-term storage in high, long-lifetime orbits after their missions.

The subject of space debris has been addressed by many international legal organizations, who are in the process of drafting guidelines based on questionnaires distributed and conferences held in 1990. Other subjects that have been the focus of particular attention by these organizations this year include treaty verification by satellites, legal implications of spaceplanes, possible actions following the detection of extraterrestrial intelligence, and legal implications of the prospective return to the Moon and human missions to Mars. In addition, discussions have continued on the specific needs of developing countries, the legal status of the geostationary orbit, commercial activities in space, and the International Telecommunication Convention.